POWER PLANT ENGINEERING

GENERATION, TRANSMISSION AND UTILIZATION OF STEAM, ELECTRIC, DIESEL AND HYDRAULIC POWER

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Linked to the Earth by Power

THE GIANT "MAINLINER" winging its way across illimitable skies is not as free and unattached as it appears to be. It is linked to the earth by agencies which, though invisible, are as real and tangible to the pilot as are the rails to the locomotive engineer. Invisible channels of radio-frequency energy keep the giant airliner on its course; radio communication circuits maintain a steady and constant contact with the ground stations, weather reports carried on the wings of radio warn the pilots of storms and fogs, and now, within the past week, comes the announcement of the absolute radio altimeter which measures the ship's actual height above the earth with uncanny accuracy. At the airport, power in a half dozen forms contributes to safety in landing and taking off. ¶ At the Chicago Municipal Airport several weeks ago the importance of power was demonstrated by its absence. Due to the failure of a feeder cable supplying electric service to the airport, a half dozen ships were kept aloft for nearly an hour during one of the busiest periods of the evening. All the ground radio transmitters were "off" and the main lighting system was out of service causing considerable inconvenience to ships in making landings. Two ships managed to land with the aid of their own searchlight but others remained aloft until the power service was resumed. Two other ships went 90 miles north to Milwaukee to land their passengers. ¶ This power failure caused considerable agitation among some of the members of the city council and the newspapers played it up in the usual dramatic fashion, but much of this excitement was probably uncalled for. After all, the airport has been operating for some twenty years and in all of that time a single hour's interruption is little enough, but the event did bring home the fact that electric power plays an important part in modern air transport service.

WITH THE EDITORS

Together They'll Win

MANY BENEFITS may be derived from an understanding of other people's problems, particularly when the solutions to these problems affect our own work. Years ago manufacturers of power equipment took occasion to secure the cooperation of the users of their products in working out faults in design, choice of materials, inconvenience of operation, adjustments in sales agreements, and other problems that confront both manufacturer and user. Every day we learn of some equipment that has been installed in a plant as an experiment to be paid for only if it fulfills the purpose for which it is installed. Other cases have been noted where equipment is tested to destruction under operating conditions because laboratory equipment was not available for the purpose. Again plant owners have cooperated with manufacturers who are developing equipment by permitting the installation of devices on their equipment and the recording of results by the manufacturer's engineers.

Such cooperation has been of benefit to both the manufacturer and the user, not only in the development of safer and more economical equipment but also in the growth of a better and more friendly understanding between the manufacturer and his customer. With such an example before them it is not surprising that the producers and users of coal have found the two joint meetings they have held of great value to both groups.

Until recent years, the material that came out of the mines as coal was sold almost in toto without preparation for the market other than sizing and picking out large lumps of slate. The coal user was then forced to use what was delivered to him whether it was suited to his conditions or not. He could of course specify the mine from which his coal was to come but, as every engineer knows, the variation in quality of coal from almost any mine is so great that whereas one shipment may be entirely satisfactory, the next may be decidedly unsuited for his furnace. For a time coal was purchased on a B.t.u. basis only. This seemed a reasonable method of specifying but with changes in burning methods, such problems as slagging characteristics, fly ash and sulphur fumes have presented themselves and must be solved.

Coal producers have in recent years developed a number of methods of processing their products and, to determine which is most desirable and economical for the user, they are soliciting and securing the cooperation of customers in conducting tests and other research work. It was to the discussion of fuel problems of mutual interest that the joint meetings, last year and this, of the Coal Division of the American Institute of Mining and Metallurgical Engineers and the Fuels Division of the American Society of Mechanical Engineers were devoted. While these meetings were entered into with some misgivings, the harmony with which they have been conducted bids fair to warrant their continuation at least until definite standards of quality and methods of testing can be agreed upon. When producers and consumers cooperate benefits are distributed in every direction.

Put Knowledge to Work

EDITORS of technical magazines are, we admit, prejudiced in their opinions as to what they think is the most valuable reading for the men occupied in the work of their fields, never-the-less a few thoughts on the choice and use of printed material may help readers to build up their personal efficiency in their chosen profession.

Too many of us read without an objective, merely as a diversion or entertainment, material that is neither informative, character building nor even interesting because of literary expression. Its only effect upon us is that it has served to kill time, many times we hurry through pages that do not have sufficient lure to take our minds off the every day living problems that are bothering us at the moment. Our minds contract habits like the sponge that receives water from above, delays its progress for a brief time and allows it to drip without performing any useful function.

To be of value, reading should accomplish at least one of these purposes—impart needed information, inspire to worth while action or give desirable recreation. It is to the first of these that the reader's attention is directed at this time for it is through the informative type of reading that most of our usable knowledge is obtained. Once this knowledge is obtained it has little value to the individual unless it is used in his living activities.

Sources of engineering information commonly available to the engineer are the proceedings of profession societies, technical magazines and books on special subjects or of the textbook type. Today scientific information almost invariably originates in research laboratories, application of these discoveries to the problems of industry is the work of engineers and from them comes information on the economics and efficiency of equipment employing scientific principles proven to be correct by the scientists.

Putting acquired information to work is a mental task requiring every phase of engineering skill from the conception of an idea to the perfection of operation of the finished product, and one's reading habits are the greatest aid to success in developing any new idea.

As we looked over the contents of this issue, the thought came that here are presented innumerable mental tools to be used by those who have the skill to comprehend their import, for it is they who are in the front rank of the profession and it is they who read with a purpose—a desire for information that can be put into practical use.

ACME

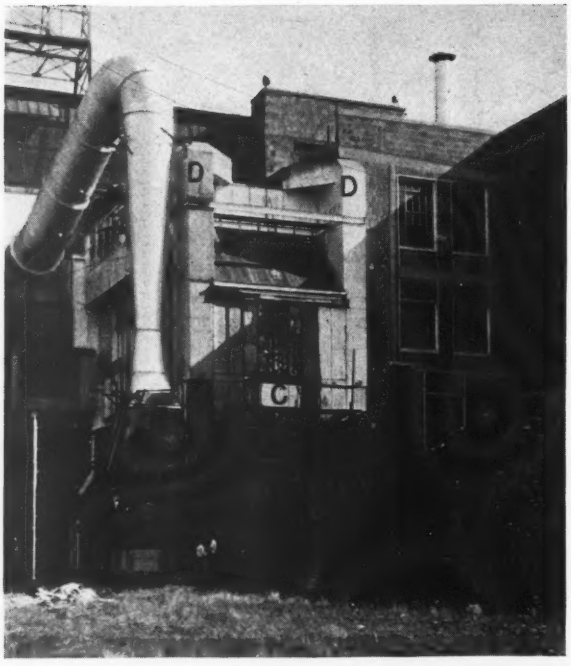

Fig. 1. Exterior view showing the semi-outdoor boiler construction in the L formed by the temporary boiler room wall on the left and the turbine room wall on the right. The turbine, boiler feed pumps and heaters are located in a extension to the auxiliary bay behind the glass brick windows A. The boiler operating floor is on the next higher level and the balcony B was built to allow access to the back of the boiler control panel. Air flow from the air heater, C, is divided between the two vertical ducts D

MANY INNOVATIONS skillfully combined in the 825 lb., 825 deg. F. extension to the Acme Plant of The Toledo Edison Co., Toledo, O., make it one of, if not the, most interesting "top" yet undertaken. Designed with the advice of G. W. Saathoff, chief engineer of Electrical Advisers, Inc., the extension centers around a single pass boiler of semi-outdoor construction, which operates either with a wet or dry bottom and incorporates control standards formulated by the operating department after two decades of experience.

Construction of the Acme Plant was started in 1916 to handle the rapidly increasing wartime load of the Toledo Railways & Light Co., predecessor of the present Toledo Edison Co. Additions and changes were made from time to time until by 1937 the turbine room held one 41,000 kv-a. frequency changer, four 235 lb. ga., 600 deg. F. turbo-generators, totaling 115,000 kw. (two 25 and two 60 cycle) with space for an additional machine. Twelve boilers fired by underfeed stokers and totaling 17,180 b.hp. supplied steam.

These boilers are arranged in three rows of four each, running at right angles to the turbine room and separated from it by an auxiliary bay running the full width of the boiler room.

The capacity of the old boiler plant, allowing normal outage for repairs, is 100,000 kw., or 15,000 kw. less than the combined capacity of the four (4) low pressure turbines. This extra margin of capacity in the turbines is the primary reason for the installation of the 6000-kw. topper which adds, therefore, about 21,000 kw. to the plant working capacity. Thus the topper installation is a transition move to higher pressure and temperature with no sacrifice to low pressure equipment and it forms the connecting link between the old plant and future additions at the upper level of pressure and temperature.

The turbine room being longer than the boiler room is wide, made the plant ell shaped and the new top plant, boiler, turbine and auxiliaries, were placed in the inner angle of the ell, as shown by Fig. 1. The new boiler is outside, with one side of the boiler casing, the back of the air heater and the top of the preheated air ducts exposed to, but insulated from, the weather. This insulation is 1½ in. of 85 per cent magnesia held in place by fine mesh chicken wire and topped with ½ in. of weather proof finish.

The back of the boiler, below the air heater, is closed by the duct leading to the induced draft fan and the exposed side of the boiler, below the boiler casing, is enclosed by a small leanto. Thus the space

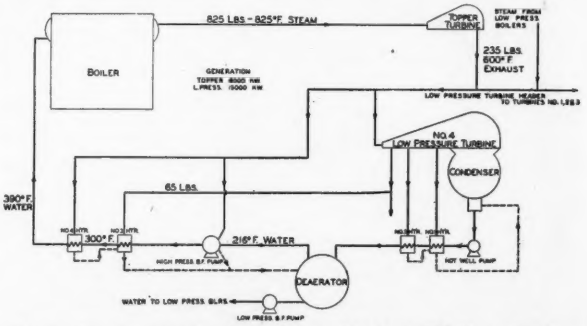

Fig. 2. The new 6000-kw. top turbine exhausts at 235 lb. to the low pressure plant header. Normally this steam goes to 35,000 kw. Unit No. 4 from which steam is extracted for the closed pressure heaters. If No. 4 is down, low pressure heater steam can be extracted from 30,000 kw. Unit No. 3. The heat rate of the complete unit approximates 15,000 B.t.u. per kw-hr. at full load

with the forced draft fan, primary air fans and pulverizers below the boiler on the ground floor is closed on two sides, but open to the auxiliary bay and boiler aisle on the remaining two sides. The induced draft fan itself is incorporated in the base of the Thermix stack and the driving motor is protected. Eventually a second high speed motor will be added on the outboard platform already provided. The temporary breeching now in place leads to one of the existing stacks, but when a second boiler is installed at the left of this one, a new stack will be built to serve both boilers and the temporary breeching removed. Due to poor soil conditions, the foundation consists of caissons sunk 65 ft. to hard pan and capped by beams.

—A Different Top

Partially outdoor construction, wet or dry bottom operation, low draft loss and auxiliary power, unique interlock and purge flow system are a few of the interesting features of the Acme Plant Extension of The Toledo Edison Co., where one 6000 kw. top turbine and one 300,000 lb. per hr., 825 lb., 825 deg. F. boiler have been in service since April.

An extension to the auxiliary bay was built to house the new 6000-kw. top turbine, two new boiler feed pumps and two vertical extraction heaters. The turbo-generator, set parallel with the boiler drums, comes within a few feet of the boiler casing and extends across the auxiliary bay with the exciter extending into the turbine room between units Nos. 3 and 4, as shown by Fig. 6. Boiler feed pumps are on the same floor at right angles to the turbine and extend almost to windows A of Fig. 1.

The new turbine is not bled, but taking steam from the new boiler at 825 lb. ga., 825 deg. F., exhausts at constant back pressure of 235 lb. ga., normally to 35,000 kw. Unit No. 4, which is bled at three points for feedwater heating, as shown by Fig. 2. If No. 4 is down, 30,000 kw. Unit No. 3 may be used in the same way. Condensate is pumped by the hotwell pumps through two low pressure heaters to the deaerating heater, as in normal low pressure operation. The deaerating heater, which is not new, is located in the old section of the auxiliary bay on the level above the new feed pumps and is supplied with steam from the auxiliary exhaust.

Contrary to usual top practice, the high pressure boiler feed pumps take their suction direct from the deaerating heater at 216 deg. F. and not from the low pressure boiler feed pump discharge. They then pump through a primary heater, supplied with 65 lb. steam bled from Units No. 3 or 4, and a secondary heater, supplied with steam at the cross-over pressure of 235 lb., so that the feed water enters the boiler at about 390 deg. F.

As with most top plants, the boiler room is the most interesting, in this case doubly so because the boiler itself is not only new and different but the entire installation is replete with innovations and departures from conventional practice. As shown by the cross section at the left of Fig. 4, the boiler is a special 3 drum B. & W. design with 2½ in. O. D. tubes in the rear rows, 3¼ in. O. D. tubes in the front rows and 7940 sq. ft. of counterflow convection superheater surface. The furnace, 23 ft. wide, is of irregular shape, completely water cooled with 3¼ in. O. D. Bailey stud tubes placed on 6 in. centers and backed with insulating blocks. The furnace, with a volume of approximately 9950 cu. ft., is separated from the boiler proper by a screen and stud tube baffle as shown in detail by the photographs, Fig. 5.

Eleven tubes emerge from each sidewall midway of the ash pit at about the level of the mud drum,

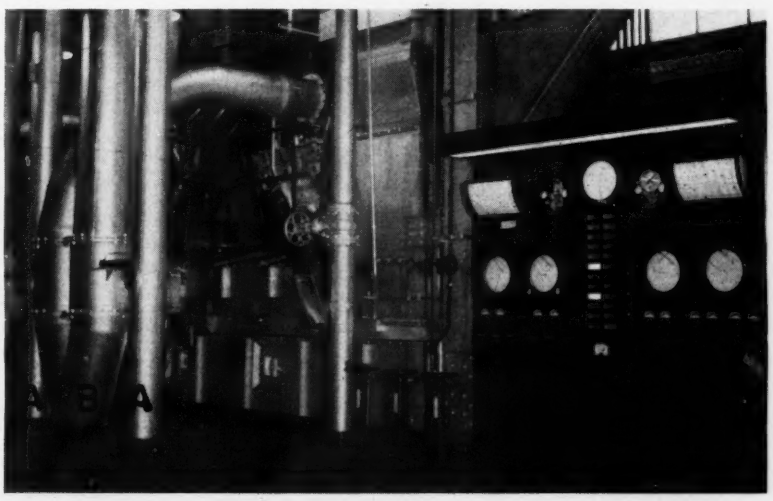

Fig. 3. Front of the boiler and the control panel

To insure positive coal feed, the three mills are fed by the four downcomers, split as shown by Fig. 4, so that each mill is fed from two sources. Automatic control is provided, but the regulators on the forced, induced and primary air dampers are grouped so that the operator can shift to remove manual operation from the three handwheels (at the left of the panel) without delay. Impending changes requiring the attention of the operator are detected by the interlock system which rings an alarm and illuminates the proper window on the board, warning the operator what to expect. On the boiler panel the instruments are, from right to left: top row, mill drafts, gas controller, steam pressure, master controller, boiler drafts; second row, mill temperatures, water level, boiler alarm system, flow meter, gas temperatures; bottom rows, ammeters and control switches for mills and fans.

extend varying distances into the furnace and turn upward. At the level of the lower burners they alternate with the front row of boiler tubes and form a vertical solid stud tube wall up to the top of the furnace.

The double burner arrangement with vertical firing is unique and is the main feature around which the unit was built. Three burners on the upper level are for dry bottom operation with coal having a high fusing temperature ash. The two burners on the lower level are for wet bottom operation with lower ash fusion temperature coals. All five burners are of the B. & W. Intertube type and the two upper outside ones incorporate gas burners so as to handle coke oven gas which is available at times. All burners are provided with gas lighters and electric ignition.

Floors and ashpit are designed especially for this dual operation. Both the front and rear floor are water cooled, covered with flat cast iron blocks and terminate in overhanging lips. For dry bottom operation ash is blown from the front of the furnace toward the ash pit by steam jets issuing from slots in the lower side of special nozzles in the floor as shown by Fig. 5. These nozzles, spaced on 18 in. centers, are in 5 rows, the first 10½ in. from the front wall header, the others at 3 ft. 9 in. intervals.

When changing from dry to wet bottom operation, dry ash is allowed to build up until the nozzles are covered. The cooling effect of the floor is sufficient to maintain a layer of this high fusion ash in granular form, but the temperature gradient is quite steep. The increased furnace temperature from the lower level burners eventually causes slagging and the formation of a crust which acts as a secondary floor from which a low fusing temperature ash readily flows over the lip of the ash pit to the deintegrating jets. It has already been domonstrated that the furnace operates successfully with either a dry or wet bottom, and, that the change from dry bottom to wet bottom can be made readily. It remains to be seen whether an operating procedure can be developed for changing from wet to dry operation without shutting down the unit and cleaning the furnace floor.

Beyond the furnace, the gases make a single pass through the boiler, flow vertically downward through a 37,600 sq. ft. tubular air heater, and make a U turn to the base of the Prat-Daniel Thermix stack. The induced draft fan in the base of the stack is arranged for two speed operation, and has a maximum rated capacity of 360,000 lb. per hr. of 450 deg. F. gas at 4.25 in. w.g. Motors are protected from the weather by corrugated steel sheds as shown by Fig. 1.

The forced draft fan, a Sturtevant Turbovane with vane control, also with two motors, has a maximum rated capacity of 68,000 c.f.m. at 9.0 in. w.g. and 100 deg. F. This fan is located almost directly under the air heater as shown by Fig. 4, which does not, however, show the direction of air flow distinctly. The air heater is of the double C type and the fan discharge is split. Air enters the heater horizontally

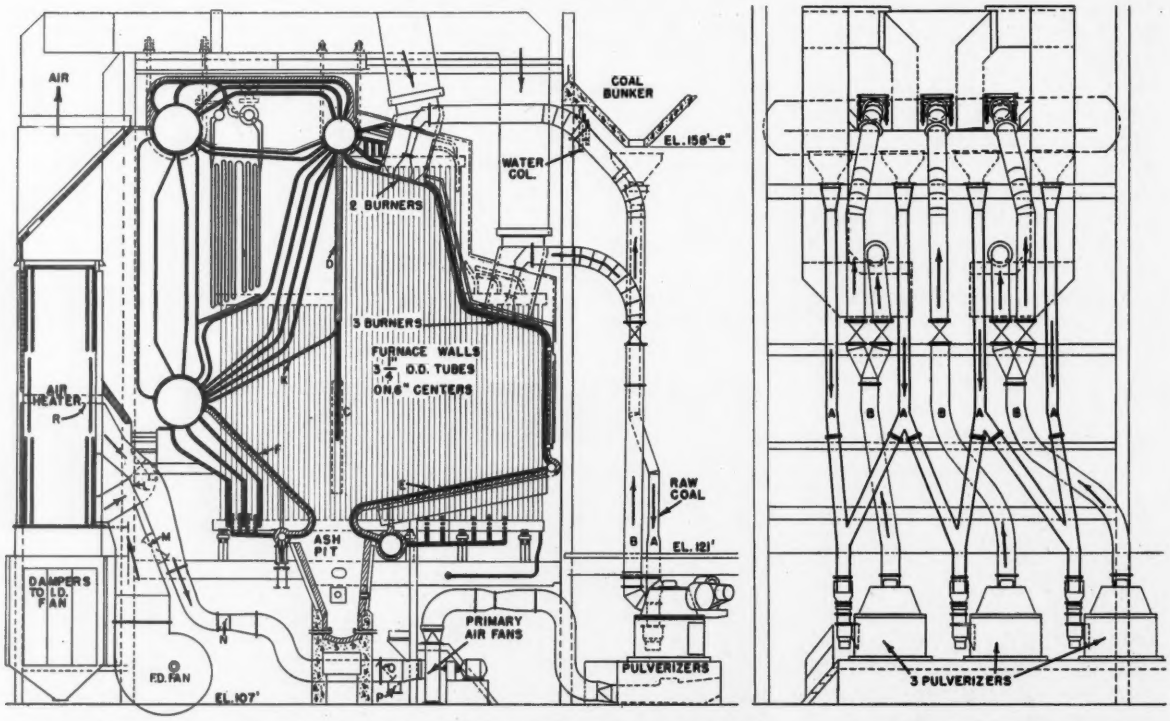

Fig. 4. Cross section and front elevation of the 300,000 lb. per hr., 825 lb. ga., 825 deg. F., single pass boiler designed for either wet or dry bottom operation

As shown at the right, raw coal downcomers A are split so that each mill has two sources of supply. The two outside mills supply either the upper or lower level burners, but the center mill supplies only a single burner on the upper level. Lettering corresponds with the lettering on the boiler room photograph, Fig. 3, and the furnace interior photograph, Fig. 5, taken to show the furnace, screen and floor arrangement. Note the dampers L, M, N, O and P for control of primary air flow and temperature. Dampers L and M are manually operated and normally control air temperature to all mills. Damper N is operated by a regular, either automatically or remotely. Beyond N the primary air duct splits into three branches and air temperature to individual mills can be controlled from the operating floor by dampers O and P during emergencies.

from both sides, turns upward and outward and leaves horizontally at the top from both sides. A bypass damper R on each side between the inlet and outlet boxes provides means for air temperature and forced draft fan duty control.

Primary air arrangements, which have been unusually well worked out, are more clearly shown in the drawing. The general idea was to regulate the air flow and temperature to all primary air fans in parallel by single dampers and then provide means for final adjustment to meet the individual needs of each mill.

supply burners on either the lower or upper level but the middle mill No. 2 has only a single burner on the upper level. Power for all fuel auxiliaries on mills No. 1 and 3 are taken from the generator leads of the new machine, but auxiliaries for No. 2 mill are supplied from the station bus, in order to start up, or, operate on limited capacity, when the top turbine is down. The fuel auxiliaries, like all auxiliaries in the new extension, are driven by 440 v. motors supplied through air break circuit breakers.

Control is centered at the boiler panel shown by

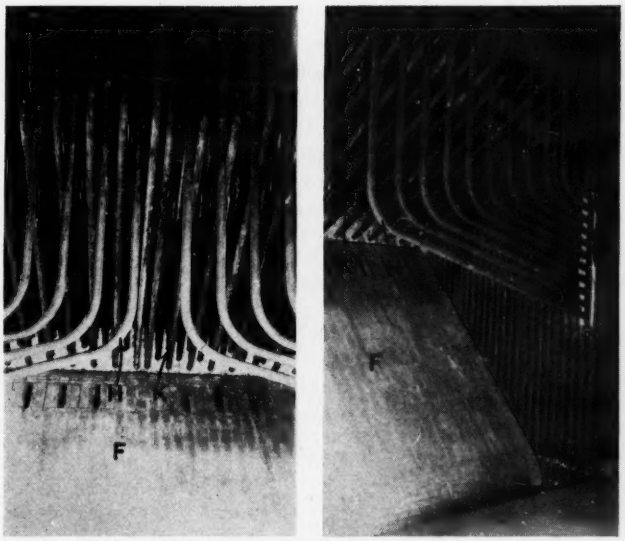

Fig. 5. Interior view of the furnace

The left hand view taken from the middle of the furnace near the front wall shows the inspection doors on the rear floor and the screen tubes coming in from both sides. As illustrated by the middle photograph eleven tubes enter each side wall at A, turn upward at H and alternate with the first row of boiler tubes K to form the solid stud tube wall D which extends from the lower burner level to the front steam drum. The right hand view shows the furnace floor and the provision made to blow the dry ash into the ashpit with steam jets. The pipes project about 1 in. above the cast iron floor blocks and have slots on the lower side. Five rows of pipes 3 ft. 9 in. apart and spaced on 18 in. centers across the width of the furnace are provided. Lettering on the photographs corresponds with that on the cross-section Fig. 4.

Primary air can be taken from two points on the air heater, in any desired proportion, under control of damper L. As an added precaution against high temperatures, damper M gives a direct bypass of cold air from the forced draft fan discharge to the primary fan section. Flow to all three mills is controlled by damper N and proper division of load is maintained by use of this single damper over the full range of operation. Beyond this damper the duct splits into three branches, with dampers O and P in the inlet of each primary air fan and movable from the boiler room operating floor for emergency use. All primary air piping is covered with 1 in. of insulation and ½ in. of hard finish cement.

The three primary air fans are under the boiler with three B. & W. Type B mills directly in front. The three mills are supplied with raw coal from an overhead bunker by four downcomers, split as shown by the elevation in Fig. 4, so that each mill has two sources of supply. Windows in the downcomers at the operating level enable the operator to detect bridging or stoppages in any branch. Coal for the new boiler is brought into the plant by the belt conveyor serving the old boilers on the other side of the aisle. It is then delivered to the new bunker by a short cross conveyor. Scales, installed between the bunker outlet and each of the four raw coal pipes to the mills, are used when testing.

As explained earlier, the two outside mills can

Fig. 3 and consists of a conventional Bailey air operated control modified in detail to meet the needs of an extensive purge-flow interlock system[1] developed at the plant. Contrary to usual practice, the induced draft, forced draft and primary air damper regulators are grouped directly under the board and connected to the dampers by shafting. Any or all of the three regulators can be shifted from automatic to remote control by the operator from the three hand wheels at the left of the control panel (Fig. 3). The interlock system, based primarily upon the maintenance of purge flow through the furnace is extended to a complete signal system warning the operator of high air temperatures, dampers nearing the wide open position, and other conditions that might require his attention.

Although the maximum capacity of the boiler is expected to reach 300,000 or 350,000 lb. per hr. with the high speed forced and induced draft fan motors in service, operation so far has been limited to a maximum of about 250,000 lb. per hr. At this output the draft loss from the entrance of the furnace to the air heater outlet is 2¼ in. w.g. At the same load the auxiliary power consumption is approximately 620 hp. divided as follows: Induced draft fan, 165; forced draft fan, 110; three primary air fans (total), 115; three mills (total), 230 hp.

[1]An article describing the details of this interlock system and its relation to the combustion control system is being prepared by Paul Gravelle, Acme Station, The Toledo Edison Co.

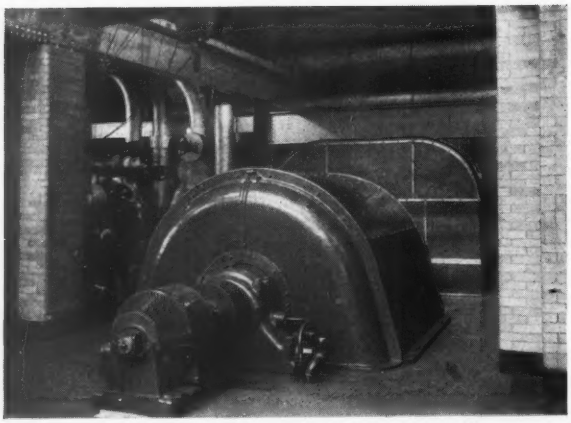

Fig. 6. The new 6000 kw. top is located in an extension of the auxiliary bay of the station. The exciter extends through the old turbine room wall between units No. 3 and 4. New boiler feed pumps are located just to the left of the generator. The side of the new boiler is visible just beyond the turbine

Because of the low draft loss and the arrangement of the induced draft fan and stack, the boiler can be operated up to 50,000 lb. per hr. on natural draft without either the forced or induced draft fan. Using the induced draft fan alone without forced draft the output can be boosted to 60,000 lb. per hr., or, reversing the operation and using the forced draft fan without induced draft, 110,000 lb. per hr. In operation the boiler is staple and the distribution of water uniform. During a trial of safety valves, two, with a total capacity of 275,000 lb. per hr., opened at once and the water level raised only about 10 in. Normally the regulator holds the level within 1 in. plus or minus.

A full capacity bypass reducing valve and desuperheater station were not installed inasmuch as the major repairs on the boiler and turbine will be done at the same time. For starting purposes, however, a simple station with a capacity of 80,000 lb. per hr. has been provided with the pressure drop all taking place in a length of small pipe so as to eliminate reducing valves. Desuperheating is accomplished by five small nozzles installed in a cross, which forms a right angle turn in the steam path, thus creating turbulence for mixing water and steam. The spray nozzles are supplied from the low pressure plant feed lines.

Piping is plain carbon steel with annealed shop welds only. All joints have small tongue and groove welding neck flanges, with a stainless steel gasket of 125 Brinnell hardness. Bolts, of A. S. T. M. A-96 steel, threaded 12 to the inch, were tightened by the elongation method, using a special micrometer.

The Toledo Edison Co., Toledo, O., List of Equipment—Acme Plant Extension

Steam Generating Unit—Babcock & Wilcox Co. 3 drum Spl. No. 46 single pass type fired by pulverized coal with 5 burners on two levels. Maximum capacity 350,000 lb. per hr., 825 lb. ga., 825 deg. F. at superheater outlet. Boiler surface 18,250 sq. ft., water wall surface 3708 sq. ft., superheater surface 7940 sq. ft. Air heater 37,600 sq. ft. double C type with 2½ in. I.D. tubes. Furnace volume 9950 cu. ft.

Forced Draft Fan—B. F. Sturtevant Co., one No. 130 Turbovane, with inlet vane control and driven by 75 and 125 hp. G.E. motors. Low speed 720 r.p.m., cap. 55,000 c.f.m. at 6.5 in. H_2O and 100 deg. F. High speed 870 r.p.m., cap, 68,000 c.f.m. at 9.0 in. H_2O and 100 deg. F.

Induced Draft Fan and Stack—Prat-Daniel Corp. Thermix. Fan driven by G.E. 150 and 300 hp. motors. Low speed 870 r.p.m., cap. 300,000 lb. per hr. at 2.35 in. H_2O, 450 deg. F. gas. High speed 1160 r.p.m., cap. 360,000 lb. per hr. at 4.25 in. H_2O and 450 deg. F.

Pulverizers—Babcock & Wilcox Co. Three size 150 Type B ball mills with a normal capacity of 6 t. per hr. each. Driven by 100 hp. induction motors.

Primary Air Fans—B. F. Sturtevant Co. Three, each driven by 50 hp., G.E. motors.

Coal Burners—Babcock & Wilcox Co., 5 intertube type, 3 on upper and 2 on lower firing level.

Gas Burners—Babcock & Wilcox Co., Two, one in each of outside upper coal burners.

Burner Ignition System—General Electric Co.

Gas Shutoff Valves and Control—Ruggles-Klingemann Mfg. Co.

Boiler Feed Pumps—Worthington Pump & Mach. Corp. Type UX2. Capacity 615 g.p.m. each at 2495 ft. head, 3550 r.p.m., taking suction from deaerating heater at 216 deg. F. One driven by 600 hp. Terry turbine, one dual drive with 500 hp. G.E. motor and Terry 600 hp., 230 lb., 600 deg. F. non-condensing turbine.

Feedwater Regulator—Bailey Meter Co.

Water Column—Diamond Power Specialty Corp.

Ash Hopper—Sluice and siftings handling system—Allen-Sherman-Hoff Co.

Coal Conveyor—Robins Conveying Belt Co. Cross conveyor and distributor from conveyor over old bunker.

Piping—Midwest Piping & Supply Co. Only annealed shop welds used. Joints small tongue and groove with stainless steel gasket.

Soot Blowers—Diamond Power Specialty Corp.

Valves—
- Safety—Consolidated, Ashcroft Hancock Co., Inc.
- Feedline Stop Checks—The Edward Valve & Mfg. Co.
- Large Cast Steel Checks—The Edward Valve & Mfg. Co.
- Blowoff—Yarnell-Waring Co.
- Main Steam Line—The Chapman Valve Mfg. Co. Nitroloy seats and discs.
- Feed Water Line—The Chapman Valve Mfg. Co. Stainless steel.
- Diaphram Operated Valves — The Swartwout Co., S-C.

Combustion Control—Bailey Meter Co.

Boiler Panel and Instruments—Bailey Meter Co.

Extraction Heaters—Griscom-Russell Co. Two LSU vertical type. High pressure heater designed to use 235 lb. steam and heat 600 g.p.m. from 280 to 370 deg. F. Low pressure heater using 30-50 lb. ga. steam extracted from No. 3 or 4 turbine and designed to heat 600 g.p.m. water from 216 to 280 deg. F. Both heaters have ⅝ in. O.D. Admiralty metal tubes.

Turbo-Generator—General Electric Co. One 6000 kw. 3600 r.p.m. turbine taking steam at 825 lb. ga., 825 deg. F., exhausting at 235 lb. ga. and driving at 13,200 v. generator and 40 kw. direct connected exciter.

Turbine Crane—Whiting Corp., 50 t.

Insulation—Johns-Manville, pipe lines and boiler exterior.

Fig. 7. View of the dual drive boiler feed pump. The end of the top turbine is just visible at the extreme right

STEEL PLUS

With the advent of high temperatures in power plants and industry and a multitude of industrial demands involving oxidation and corrosion resistance, light weight, welding and machineability, steel is no longer just steel. It is Steel Plus and it behooves the modern engineer to know what the plus is. For convenience and to increase the readability of the article, technical information has been summarized in the table.

R. STARK VON ROGAR

SCIENTISTS made alloys of iron and chromium long before the present "age of steel" but the fact that the mixtures did not rust was regarded in a decidedly secondary light. In 1913 Brearley, an Englishman, focused attention upon the non-corrosive properties of such alloys by making a steel containing 13 per cent chromium and calling it "stainless steel." Since, almost every known element has been added to Brearley's original analysis in attempts to improve the physical and chemical properties of a non-corrosive steel.

Consequently the engineer is confronted today with dozens of commercially available stainless and heat-resisting steels, with a great many trade names for the same material. Obviously he cannot become sufficiently familiar with the subject of metallurgy to always specify the steel best suited to his needs any more than the steel manufacturer can be an authority on the problems of every customer, hence the utmost cooperation between the two is essential.

There is nothing basically wrong with leaving the choice of the analysis to the vendor or consultant for both are anxious to see a good job done, nevertheless, the engineer should certainly be in a position to understand something about the materials to be used in his plant. To this end a general knowledge of the fundamental stainless and heat-resisting steel compositions would be helpful. Such information would save the engineer considerable time in making preliminary designs for he would know which of his ideas were suited to the material the steel man would be likely to specify for a particular job. Further, if he has a good conception of the data regarding operating conditions that are required before a material can be specified he can be of much assistance to the steel man, and time and money will be saved. Above all, he must realize there is no panacea regardless of the number of analyses on the market and each has a definite purpose.

The following has been written for the engineer who has never studied the subject and no attempt is made to discuss the metallurgical effect of the various alloys added to steel to produce stainless or heat-resisting properties. For those who wish to delve more deeply into the subject of metallurgy the works of Sauveur and Moneypenny are suggested.

Corrosion Resistance

Whether one considers Brearley's original 12 per cent chromium steel, or, a more complicated analysis, it is stainless for the same reason. That reason is an invisible film of oxide on the surface of the metal, much the same as the oxide film that forms on aluminum and makes soldering difficult. As long as that film is preserved the steel is immune to corrosion; but let it be continuously broken down and the steel will suffer the same as a common plain carbon steel. Thus, simple chemistry shows that the present day stainless steels will not stand up under strong reducing agents such as hydrochloric acid, certain gases, weak sulphuric acid, etc., because those agents break down the protective film and prevent it from reforming. Likewise certain types of abrasion may result in the continual destruction of the film.

Chromium is the element that produces the protective oxide on stainless steel and in varying amounts upwards of 11 per cent it forms the basis of all stainless steels. At least this amount is required to produce stainless properties. In general, corrosion resistance increases with chromium until about 30 per cent of the element is present. To be effective in this respect the chromium must be in solid solution with the pure iron constituent of the steel. Unfortunately chromium has a strong tendency to combine chemically with the carbon in the steel and the carbides so formed do not contribute to the stainless properties of the steel. Instead this combination of chromium and carbon prevents certain plain chromium stainless steels from being hardened by heat treatment as no carbon remains to form the iron carbon compound which causes steel to harden. It may also rob the pure iron of enough carbon to insure corrosion resistance.

Nickel, in combination with chromium is also important to certain stainless steels and in amounts above seven per cent adds to the corrosion resistance by certain agents. The presence of such quantities also changes the steel metallurgically, producing chromium-nickel-iron-carbon alloys which cannot be hardened by heat treatment even though the carbon content is great enough to permit an analogous plain chromium steel to harden. These are known as austenitic steels. For some applications the nickel content may exceed the chromium content. Manganese has also been used to replace all or part of the nickel as it acts similarly metallurgically. In a newly developed analysis copper replaces the nickel.

Among the other alloys often added to chromium and chromium-nickel steels are: molybdenum or copper in small amounts to increase corrosion resistance under certain conditions; selenium or sulphur to improve machineability; and titanium, boron, vanadium, or columbium to prevent inter-granular corrosion (attack at the grain boundaries), to improve the weldability and eliminate hardening upon cooling quickly

Tabulation of the physical and chemical properties of the various group of alloy steels. More detailed information regarding application is given in the footnotes A to H.

COMPOSITION.		ULTIMATE STRENGTH	YIELD POINT	ELONG IN 2 IN.	REDUCT. OF AREA	CREEP STRENGTH LB. / SQ. IN. FOR 1 % ELON. IN 10 M. HR.			HIGH TEMP. STRENGTH LB. / SQ. IN AT[1]			LIMIT OF OXIDATION	FABRICATION 0= POOR OR WORST 5= GOOD OR BEST			TYPICAL APPLICATIONS	NOTES
		LB./SQ. IN.	LB./SQ. IN.	%	%	1100°F	1300°F	1500°F	1250°F	1500°F	1700°F	RESIST. °F	MACH.	WELD.	DRAW.		
PLAIN 0.20% C STEEL	ANNEALED	60,000	40,000	35	65	2000	700						5	4	4		
4-6% CR, 0.15% C, 0.5 % MO.	ANNEALED	90,000	65,000	30	70	4100	2000		35,000			1150*	3	4**	3	STILL (OIL) TUBES, SUPERHEATER TUBES	A
11-16 % CR, < 0.12 % C	ANNEALED	75,000	45,000	30	60	5000	1500		16,000	10,000	8500	1500	2	2	1	CHEMICAL EQUIPMENT WHERE SOME DISCOLORATION IS PERMISSIBLE. RESISTANT TO ATMOSPHERIC CORROSION UNDER MOST CONDITIONS.	B
	HEAT TREATED[2]	190,000	160,000	15	50												
FREE MACHINING GRADE	ANNEALED	75,000	45,000	30	60				16,000	10,000	8500	1500	4	0	0		
	HEAT TREATED	150,000	138,000	17	50												
16-18% CR, < 0.12% C	ANNEALED	82,000	50,000	25	45	8000	1450		17,000	8000	5000	1600	1	1	4	CHEMICAL APPARATUS, FOOD INDUSTRY	C
	COLD ROLLED	125,000	100,000	9													
11-18% CR, > 0.12% C	ANNEALED	75,000±	PROPERTIES VARY GREATLY WITH CHEMICAL COMPOSITION AND HEAT TREATMENT													CUTLERY, CRUSHERS, SHEARING DEVICES, FANS, BLOWERS, SURGICAL EQUIPMENT.	D
	HEAT TREATED	220,000±															
16-18 % CR, 1-2 % NI, 0.15 % C	HEAT TREATED	175,000	135,000	15	50	STRUCTURAL STEEL-SUFFICIENT CORROSION RESISTANCE FOR AIRCRAFT ETC.							1	3-2	4	AIRCRAFT — BRITISH ESPEC.	D
25-30 % CR, 0.25 % C ±	ANNEALED	85,000	52,000	25	45		850		25,000	12,000	6500	2200	1	0-1	0	FURNACE DAMPERS, PYROMETER PROTECTION TUBES, MINING EQUIPMENT.	E
18 % CR, 8 % NI, < 0.15 % C	ANNEALED	85,000	40,000	60	70	12,000	4200	850	50,000	30,000	18,000	1600	1	5	5	ARCHITECTURAL, BOTH STRUCTUAL AND ORNAMENTAL, CHEMICAL EQUIPMENT, SUPERHEATERS, HIGH TEMP. PIPING, VALVES & TRIM DAIRY & FOOD INDUSTRY	F
	COLD ROLLED	180,000	150,000	10													
FREE-MACHINING GRADE-ANNEALED		85,000	40,000	55	70				40,000	25,000	15,000	1600	3	3	3		
18 % CR, 8 % NI, < 0.15 % C, + TI OR CB	ANNEALED	VERY SIMILAR TO SIMPLE "18-8"				13,000	4600	850	55,000	32,000	18,000	1600	2	5	4	ENGINE AND TURBINE PARTS, AIRCRAFT, PAPER MAKING INDUSTRY APPARATUS, CABLE, WIRE, SHIP RIGGING HOSPITAL EQUIPMENT, OIL REFINING EQUIPMENT	G
	COLD ROLLED																
18 % CR, 8 % NI, < 0.12 % C, 2-3 % MO.	ANNEALED					20,000	12,000	3000	65,000	35,000	18,000	1700	2	5	4		
	COLD ROLLED																
25 % CR, 12 % NI, < 0.20 % C	ANNEALED	100,000	50,000	57	57	135,000	4900	900	55,000	32,000	15,000	2200	2	4	4	KILN LININGS, STILL TUBE AND SUPERHEATER SUPPORTS, PUMP-PARTS, FURNACE PARTS RABBLE ARMS HEAT-TREATING EQUIPMENT, FANS, BLOWERS	H
25 % CR, 20 % NI, < 0.20 % C	ANNEALED	100,000	50,000	50	55	135,000	5300	1000	50,000	30,000	13,000	2200	2	4	4		

ABBREVIATIONS: CR = CHROMIUM NI = NICKEL C = CARBON < = LESS THAN MO = MOLYBDENUM TI = TITANIUM CB = COLUMBIUM > = GREATER THAN

FOOTNOTES

[1]Metal temperatures considering the effect of the cooling media such as steam in superheater tubes.

[2]Heat treatment for good all around properties and not necessarily for maximum strength.

*Not completely resistant.

**Welds to be annealed or Ti or Cb grades of steel used.

A—Increasing Cr to 8 or 9 per cent increases heat resistance more or less directly. Creep strength of 4-6 per cent Cr steels without Mo or W not much higher than plain steel. Mo and W also increase high temperature strength and oxidation resistance. Ti or Cb render them non-hardenable; beneficial in welding; increases oxidation resistance.

B—Resistance to a large number of milder corrosive agencies. May be hardened, tempered and annealed. Free machining properties provided by additional elements.

C—Greater corrosion resistance than "B". Non-hardenable but respond somewhat to annealing. May be cold-worked for improved physical properties.

D—Responsive to heat treatment. Possess good corrosion and abrasion resistance, maximum obtaining in hardened condition. Lack ductility and toughness. Small amounts of nickel, molybdenum, vanadium or cobalt improve hardenability, permitting lower carbon contents and greater ductility when heat treated for high strength; see next composition.

E—Perhaps the ultimate in plain chromium analyses. Non-hardenable but respond slightly to annealing. Not affected by flue gas and similar agencies. Suffer embrittlement between 750 and 1025 deg. F. Ti or Cb improve forging properties.

F—Probably most widely applied stainless steel. Austenitic, annealed by rapid cooling, hardened by cold working. Generally more corrosion resistant than plain Cr steels of same Cr content. Cr varies approximately between 16 and 20 per cent and improves physical and chemical properties proportionately. Nickel ranges from 7-14 per cent high creep strengths obtaining from higher nickel content. Free machining grade contains additional elements. Embrittlement encountered between 1200 and 1500 deg. F. and steel is susceptible to intergranular attack if not annealed after welding or similar heating.

Integranular corrosion is a form of corrosive attack to which austenitic stainless steels are susceptible after being exposed to temperatures which cause some of the chromium to leave the pure iron constituent and combine with the carbon. This robs the iron of some of the chromium needed to insure corrosion resistance and the phenomenon is such that the depletion and attack occurs at the grain boundaries. Two remedies exist, one is heat treatment (rapid cooling from a temperature above that causing the precipitation of the chromum-carbon combination), the other is stabilizing the steel with the addition of an element which combines with the carbon before the chromium has a chance to do so. Titanium and columbium are widely used for this purpose. The practical aspects of this subject are very apparent in connection with welded structures. Obviously when a weld is made the metal at some distance from the weld will have been at the critical temperature. If annealing of the entire object is possible the plain austenitic steel may be used, if not the titanium or columbium types should be used.

G—Ti or Cb (other less common elements also) render steel immune to intergranular corrosion. Mo improves heat and corrosion resistance. High Si increases oxidation resistance.

H—Analogous to 18-8 group but possess greater corrosion and oxidation resistance. Additional elements have same effect as on 18-8.

from a high temperature. Nickel in small amounts is at times added to the plain chromium stainless steels in the interest of physical properties.

By heat resistance of steel is generally meant resistance to high temperature oxidation or scaling, resistance to creep (plastic deformation over long periods of time at high temperatures) and maintenance of tensile strength at elevated temperatures. Chromium and chromium nickel in combinations of roughly 16 per cent of the former and seven of nickel to 30 per cent of both are the basis of this property. Oxidation resistance increases with the chromium content but creep strength falls off above 16 per cent chromium, so nickel is added where this property and high temperature strength is important.

Molybdenum or tungsten are often added to increase creep strength. Tungsten alone promotes high temperature strength but does not produce oxidation resistance. Large amounts of silicon (plus other alloys), are used in steels for internal-combustion engine valves (small amounts of silicon and manganese are present in all steels being necessary to the manufacturing processes), and aluminum is also used in addition to chromium in some heat-resisting analyses.

Physical Properties

In addition to corrosion and heat-resistance many of the alloys possess excellent physical properties at room temperature. One analysis in particular (18 per cent chromium 8 per cent nickel) exhibits such a high strength-to-weight ratio that it is used extensively for the construction of light weight high speed trains, where corrosion resistance is a secondary consideration. In structures, where deflection of a member is the limiting factor, redesign of the usual members is often necessary to permit realizing on the high strength of the steel. When this is not possible weight reduction may still often be effected through reduced sections permissible because no allowance for loss of section by corrosion is necessary.

Heat treatment affects these alloys in various ways. Some may be hardened by quenching from high temperatures and annealed by slow cooling while others are annealed by quenching and harden only by cold rolling, thus acting like brass. Others, which cannot be hardened by quenching, respond slightly to annealing. This permits improving the physical properties of welds which would otherwise be too brittle.

Obviously the way is not always clear, many of the alloys being subject to various peculiarities. Some become brittle within certain temperature ranges; others are tough enough at high temperatures but lose ductibility upon cooling to room temperature. This latter makes rough handling during clean periods, for example, impossible. Steels of a third type lose much of their corrosion resistance when tempered at certain temperatures and a fourth group may be subject to intergranular corrosion.

General Types of Stainless Steels

Closely following Brearley's original 12 per cent chromium 0.30 per cent carbon steel came a host of plain chromium steels with alloy contents ranging from 11 to about 30 per cent chromium and as many high chromium-high nickel steels of the now familiar 18-8 type (18 per cent chormium, 8 per cent nickel). Many of these compositions are modified by the addition of other elements.

It has long been evident that steel with much less than 11 per cent chromium is not always truly stainless, however, the 4 to 8 per cent chromium steels may logically be mentioned here because of their increasing usage in the power plant for applications where heat resistance in a moderate degree is required. These steels, especially those with 4 to 6 per cent chromium were developed primarily for the oil refining industry where a steel with greater life than that of plain carbon steel was required; but the increased cost of the more highly alloyed varieties was not warranted because of early obsolescence of equipment. The 4 to 6 per cent chromium steels have been found to be as much as ten times more resistant to corrosive agents containing sulphides than ordinary steel, the oxidation resistance at 1000 deg. F. being about tripled.

The accompanying tabulation presents representative physical properties of some of the more common types of stainless steel. Space limitation necessitated broad ranges in composition and omission of many variations in analysis and heat treatments; however, the values given are reasonable for steels at about the midpoint in the alloy ranges shown. The figures are for rolled material; castings differ in properties and usually in composition. (It is planned to cover castings and their properties in a subsequent article.) The foot notes amplify the table in many respects and will help the reader visualize the effect of changes in heat treatment and composition.

Those who wish to study the steels further would do well to communicate with the various steel manufacturers who have compiled much data on the physical and corrosion resisting properties of stainless steel and who usually have this information in the form of pamphlets for gratis distribution and often offer a consulting service to prospective users.

Factors Governing Selection

By this time the reader has probably realized that there are a number of factors governing the choice of the proper steel for a certain application. Generally, the following points must be carefully examined:

1. Required allowable stress.
2. Working temperature—constant or intermittent.
3. Will shock loads occur—at working or other temperatures.
4. Will there be repeated reversals of strain,—i.e. possibility of fatigue or corrosion fatigue.
5. What is the creep limit.
6. Provisions for thermal expansion.
7. Abrasion by dust, etc.
8. Method of fabrication.
9. Corroding media and extent of resistance required.
10. Required resistance to oxidation.

When the material is to be used for a new class of service, a sample should be tested under actual working conditions if this is at all possible. The value of such a field test cannot be overestimated for although laboratory tests are beneficial, the attempts made to simulate conditions encountered in practice are seldom if ever entirely successful. After the best (technically) steel for a particular installation has been decided upon, its cost must be balanced against the cost of maintenance or replacement when using cheaper steel. In many instances a compromise becomes necessary.

Low Alloy Steels, Alloy Iron, and Non Ferrous Alloys

In recent years many low alloy steels containing chromium, molybdenum, nickel, etc., have made a bid for fame as heat-resisting steels. Although they cannot compete with the high alloy steels they possess excellent high temperature physical properties and their low cost places them on an equal footing. These and the many S. A. E. steels will be described in a future article.

High- and low-alloy cast irons and many nonferrous alloys are equally as important from engineering standpoints as the steels and these too must be left for a future discussion.

And now, still another member of General Electric's famous turbine team comes to bat in the Modern Turbine series. This time it is Allen Keller who like Mr. Newman and Mr. Lyons knows his turbines generally but in addition is something of a specialist in particular branches of the art. In this article Mr. Keller tells you something about efficiencies —that efficiencies or steam rates in themselves are not necessarily a measure of plant economy. As he points out a new turbine less efficient than an existing one might be capable of saving thousands of dollars in operating costs.

MODERN TURBINES*

By
ALLEN KELLER
Turbine Engineering Dept.
General Electric Co., Lynn, Mass.

OVERALL FUEL COSTS of power generation are not necessarily proportional to turbine efficiencies or steam rates. In fact, a new turbine less efficient than an existing turbine might be able to save many thousands of fuel cost dollars. Strange as it may seem to the uninitiated, turbine efficiencies or steam rates taken by themselves are no measure of power plant economy. The amount of fuel burned under the boilers for a given amount of power output from a turbine will depend primarily on the operating steam conditions and the relationship of the turbine to other power plant apparatus—to only a limited degree will the power plant economy depend upon the efficiency of the turbine.

In this and a succeeding article, the concept of steam rate as a measure of turbine performance will be modified. Complicated looking "heat balance diagrams" will be broken down into their basic elements. Their value and derivation will be explained. And most important of all, the vital relationship between fuel burned and power output will be set forth in a simple, easy-to-understand, manner.

It is customary for users of steam driven prime movers to think in terms of steam flow or steam rate and output; and turbine manufacturers usually express their performance guarantees in this form. Both quantities involved in the steam rate, steam flow and output, are concepts which are easy to understand and require no "highbrow" reasoning for their proper interpretation. The steam rate is therefore admirably suited as a basis for guarantees, and as a simple, direct statement of the performance of a steam engine or turbine it is a necessary, even if inadequate, measure of performance.

When considering the steam rate as a measure of turbine performance, the operating steam conditions must be considered at the same time and the turbine's relationship to other power plant apparatus must be known. If this were not true and steam rate alone could be used as a criterion of performance, why would anyone purchase a noncondensing turbine having a 40 or 50 pounds steam rate when a condensing turbine with a 10 or 12 pound steam rate might just as easily be installed? Were the exhaust steam from the noncondensing turbine discarded as is the exhaust steam from most condensing turbines, it would be foolish to buy the noncondensing machine. But the steam exhausted from any turbine, condensing or non-condensing, contains a large proportion of the heat put into the steam at the boiler, and noncondensing turbines discharge this heat at a temperature high enough for use in many industrial processes. Condensing turbines, in most cases, discharge their exhaust heat at a temperature too low for use, with the result that power generated by them must be charged with all the heat in the steam entering the turbine throttle. But noncondensing turbines are charged only with the heat they actually use in generating power, the heat in the exhaust steam being charged to the industrial process. Because of this basic difference between noncondensing and condensing turbines, one discharging heat that is usable, the other discharging heat which must be thrown away, noncondensing turbines usually generate power at a

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fraction of the fuel cost of power from condensing turbines.

Of course, it is not economical to exhaust more steam from a noncondensing turbine than is required to satisfy the low pressure steam demand. After the low pressure demand has been supplied with its required steam flow, any additional flow taken by the turbine is chargeable entirely to the power generated. This extra steam required for power generation over that required for process work should be passed through a condensing turbine in order to keep the total steam flow at a minimum. This explains why many plants have both condensing and noncondensing or extraction turbines. Noncondensing turbines generate inexpensive power in a plant having use for the exhaust steam; they generate expensive power in a plant which has no use for the exhaust steam.

The foundation for all feedwater heating cycles is the basic fact that, regardless of steam rate, the cost of fuel for power generation is dependent upon the amount of heat removed from the turbine at a usable temperature and pressure level. In the case of feed water heating, as in the case of noncondensing turbines, usable heat is taken from the turbine by extracting steam after it has passed through part of the turbine stages and has generated some power. Extraction from the turbine actually increases the total throttle flow required to generate a given power output, but, paradoxically, less fuel is required to obtain this greater steam flow from the boiler.

So much for a general review. Now we shall broaden our understanding of steam rate to include "heat rate". Heat rate defined is:

The heat rate of any power plant using fuel as a source of energy is the number of heat units which must be supplied for each unit of power produced.

This definition is perfectly general, may be used with any system of units and for any type of power plant whether it be steam turbine, steam engine, gasoline or Diesel engine, or any other prime mover obtaining its energy from the burning of fuel. In this article, however, the discussion will be limited to steam turbine power plants, and the heat rate will be expressed in terms of B.t.u. per kilowatt hour.

When considering a complete power plant consisting of boiler, turbine, generator, auxiliaries, etc., the expression for plant heat rate is:

$$\text{Overall plant heat rate, in B.t.u. per kw-hr.} = \frac{\left[\text{Fuel burned, in lb.}\right] \times \left[\text{Heat value in fuel, in B.t.u. per lb.}\right]}{\text{Net power generated, in kilowatt hours}}$$

This equation will give the number of heat units purchased to produce a unit of power at the switchboard. It is truly an overall efficiency factor for the plant if all the heat produced by burning fuel is chargeable to the power generated, which will be the case for a power plant whose only output is electrical energy.

As recently as 15 yr. ago the average condensing turbine power plant produced a net kilowatt hour of power for each two pounds of coal burned. (Assuming 12,000 B.t.u. per pound of coal, this would mean an overall plant heat rate of 24,000 B.t.u. per kw-hr.). In the best of today's condensing turbine steam plants a kilowatt hour of power is produced for less than a pound of coal. Such are the improvements in power plant equipment and operating conditions which have been made during the past decade or two.

After a power plant has been built and operated, the overall plant heat rate may be determined quite readily by the formula given. On the other hand, the calculation of an expected heat rate for a plant before it is built is a more involved process and requires a knowledge of the performance characteristics of all of the important apparatus in the plant. Even so, the overall plant heat rate may be estimated with small

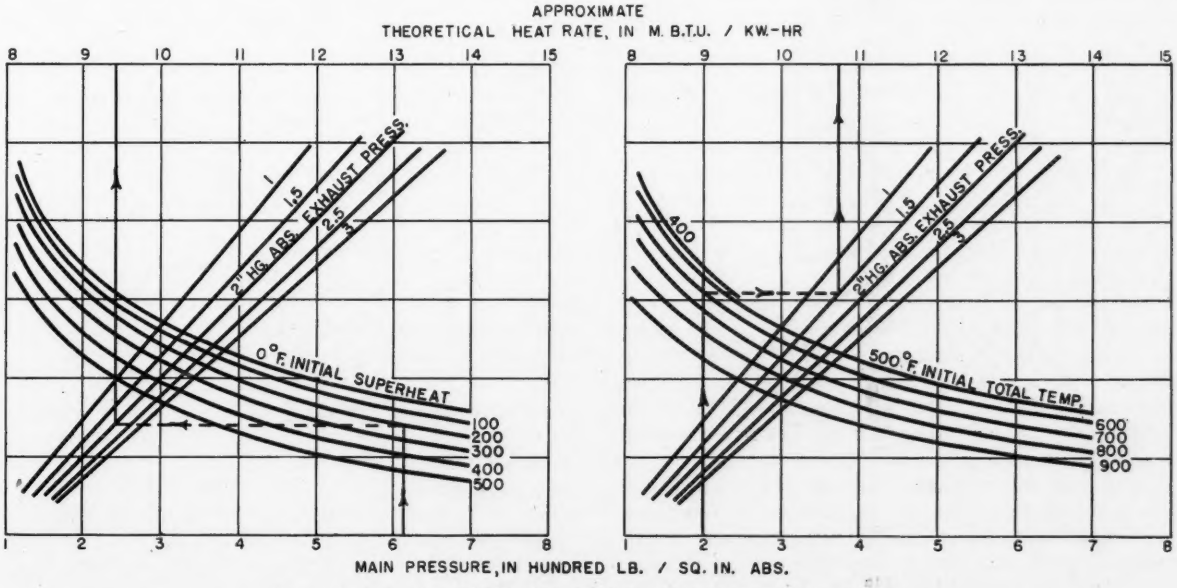


Fig. 1, A & B. Approximate theoretical heat rate for condensing turbines

NOTE: Absolute pressure in lb. per sq. in. = lb. per sq. in. gage + 15 lb. per sq. in. (at sea level). Absolute pressure, in inches hg. = 30.0 minus the vacuum in in. hg. (at sea level).

error quite quickly and without any laborious calculations.

The most important factor in the determination of the plant heat rate is the heat rate of the turbine itself.

The turbine heat rate is the number of heat units which must be supplied by the boiler *to the steam* for each kilowatt hour of power produced.

In this definition emphasis must be placed on the words *to the steam.* The turbine heat rate is based on the heat *absorbed* by the water and steam as it passes through the boiler, which is the boiler output, rather than the heating value of the fuel burned, which is the boiler input. Perhaps it would be clearer if, instead of saying "turbine heat rate," we were to say "turbine-condenser-feed-water-heater heat rate," as that is what is really meant. Steam enters the turbine throttle at a given pressure and temperature which fixes its heat content. Condensed steam is returned, as a liquid, to the boiler at some lower temperature and its corresponding heat content. The difference between the heat content of the throttle steam and the heat content of the returned boiler feed-water is the amount of heat which is chargeable to the turbine-condenser-feed-water-heater system and which would need be supplied by fuel to a 100 per cent efficient boiler. The actual fuel required will be in excess of this by an amount sufficient to offset the boiler losses. The plant heat rate takes into account the complete power plant with all its losses; the turbine heat rate considers only the turbine-condenser-feed-water-heater group and neglects all other losses. Circulating water pump power is considered as an auxiliary loss and is not charged to the turbine.

For analytical purposes, it is convenient to express the turbine heat rate in the form of an equation.

$$\text{Turbine heat rate, in B.t.u. per kw-hr.} = \frac{\left[\text{Total steam consumed in pounds.}\right] \times \left[\text{Heat content of steam at the Turb. throttle, in B.t.u. per pound.} - \text{Heat content of feed water entering boiler, in B.t.u. per lb.}\right]}{\text{Net power generated, in Kilowatt hours}}$$

$$= \left[\text{Steam rate, in lbs. per kw-hr.}\right] \times \left[\text{Heat content of steam at the Turb. throttle, in B.t.u. per pound.} - \text{Heat content of feed water entering boiler, in B.t.u. per lb.}\right]$$

Of course, when this latter equation is used for turbines operating with extraction for feed water heating, the steam rate must be based on the total throttle flow required when extracting.

It will be noticed from these equations that the turbine heat rate may be evaluated directly from the steam table and the manufacturer's performance guarantees; in fact, guarantees on large central station turbines are frequently made on a heat rate basis. The heat content per pound of steam at the throttle may be read from a steam table or steam chart at the throttle pressure and temperature. For turbines operating without feed water heating, the heat content per pound of feed water entering the boiler may be read from the steam table as the heat of saturated liquid at the turbine exhaust pressure. When turbine performance guarantees are based on operation with feed water heating extraction, the turbine manufacturer's quotation should state the condition of the feed water leaving the last heater.

The approximate overall plant heat rate may be found by dividing the turbine heat rate by the boiler, furnace, and grate efficiency and increasing the result a few per cent to allow for the losses of the auxiliary power plant equipment.

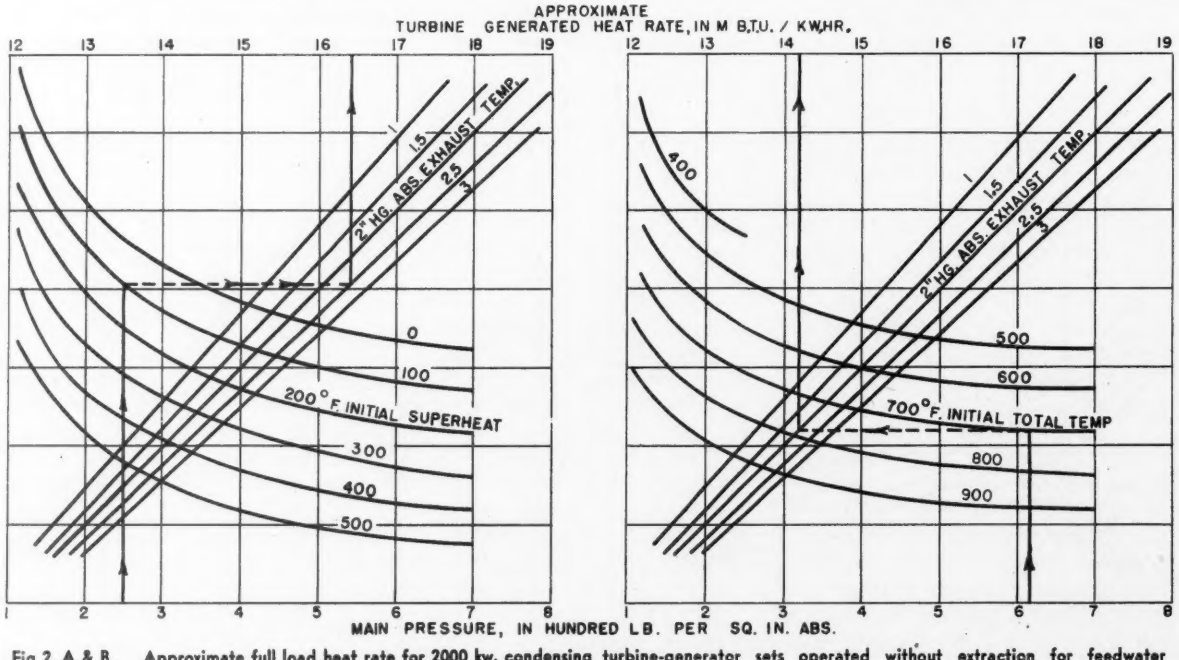


Fig 2, A & B. Approximate full load heat rate for 2000 kw. condensing turbine-generator sets operated without extraction for feedwater heating

NOTE: Absolute pressure in lb. per sq. in. = lb. per sq. in gage + 15 lb. per sq. in. (at sea level).
Absolute pressure, in inches hg. = 30.0 minus the vacuum in in. hg. (at sea level).

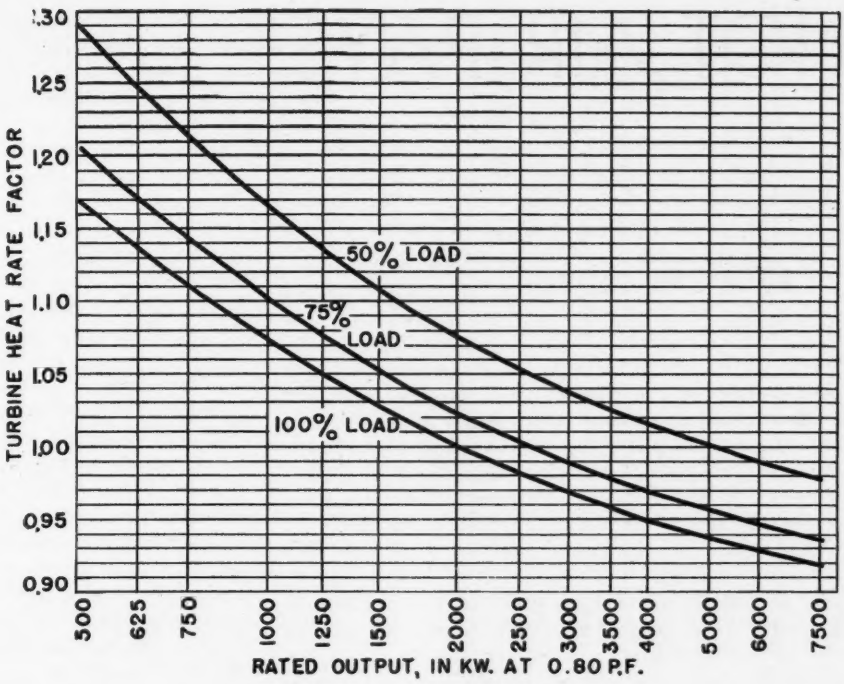


Fig. 3. Heat rate factor for condensing turbines

When making preliminary investigations of alternative steam conditions for new plants, it may be assumed that the overall plant heat rate will vary directly with the turbine heat rate; the plant heat rate being, roughly, 25 per cent higher than the turbine heat rate. This constant difference is true because the boiler efficiency will remain substantially constant over a wide range of conditions.

Before considering turbine actual heat rates, let us first examine a curve showing theoretical heat rates. Just as theoretical steam rates are valuable to turbine designers and operators as indicating the amount of steam which would be required by a perfect turbine, so are theoretical heat rates valuable as an indication of the amount of heat which would be supplied by the fuel in a plant with no losses. Figures 1-A and 1-B show the approximate theoretical heat rate for condensing turbines operating at common steam conditions. Figure 1-A may be used when the throttle temperature condition is expressed as superheat, and Figure 1-B when it is expressed as total steam temperature.

Either of these theoretical heat rate charts may be read by entering at the bottom with the absolute throttle pressure, rising vertically to the proper superheat or total temperature, proceeding horizontally to the back pressure, then rising vertically to the theoretical heat rate scale. The absolute pressure should be taken as the gage pressure plus 15-lb. per sq. in. (at sea level).

As an example, Figure 1-A shows that a turbine operating at 600 lb./sq. in. G. (615 lb./sq. in. abs.)—200 deg. F. superheat at the throttle and 2 in. Hg. abs. exhaust pressure, will have a theoretical heat rate of 9390 B.t.u. per kw-hr. This means that were it possible to have a 100 per cent efficient boiler, a 100 per cent efficient turbine and generator, and no auxiliary losses, it would be necessary to burn fuel to the extent of 9390 B.t.u. in order to generate 1 kw.-hr. of power. Actually, of course, it will be necessary to burn considerably more fuel than this to offset the unavoidable losses.

The theoretical heat rate is a useful thing to know for analytical purposes, but after all it is the actual heat rate in which the power plant engineer is interested. These may be found quickly from figures 2-A, 2-B, and 3. Figures 2-A and 2-B give the approximate *full load* heat rates for turbine-generator sets rated 2000 kw. when operating without extraction for feed water heating. Figure 3 gives the correction for other ratings and for loads less than rated output. These curves were derived by working up the actual heat rate as the theoretical heat rate divided by the turbine efficiency.

As an example of the use of the turbine heat rate charts suppose we find the straight condensing heat rate of a 4000 kw. turbine generator set designed for 600 lb. G.—700 deg. F. at the throttle, and 2 in. Hg. abs. back pressure, when carrying 3000 kw. load. . . . Since the total temperature at the throttle is given, Figure 2-B should be used for reading the basic heat rate. At 615 lb. abs.—700 deg. F.—2 in. Hg. abs., we read a basic heat rate of 14,200 B.t.u. per kw.-hr. From Figure 3, for a 4000 kw. rating operating at 75 per cent of its rated output (3000 kw.), we read a multiplying factor of 0.969. The approximate heat rate of our turbine is, therefore, $14{,}200 \times 0.969 = 13{,}700$ B.t.u. per kw.-hr. And this result is within a few per cent, plus or minus, of what would be calculated from a manufacturer's quotation on a modern turbine.

If the cost and heating value of fuel are known, it is now a simple matter to carry the calculation to its logical conclusion and calculate the fuel cost of a kilo-

Continued on page 711.

HOT AIR PAYS

Preheated combustion air, when properly applied, can increase efficiencies and capacities, reduce maintenance and, in some cases lower construction costs.

By G. Campbell Kohlar

THE AIR preheater is at once the baby and the step-child of the power plant. Most of the text books are still discussing the question of whether an economizer is a sound piece of plant equipment or not, and many of the latest books, while recognizing that there is such an animal as an air preheater, have little or nothing to say on the subject. The modern trend toward higher boiler pressures, greater capacities and increased efficiencies, not to mention the ever mounting cost of fuel, makes the recovery of every available B.t.u. in the stack gases imperative. The larger utilities and industrial plants, ever on the alert for any improvement, and with competent engineering staffs to keep abreast of all new developments, have long recognized the value of the air preheater. But there are still a great many smaller plants not equipped with air heaters which could use this method of heat recovery to very definite advantage.

Consider a 300-hp. boiler operating at 150 per cent of rating and 125 lb. pressure. Such a unit is typical of those which are not equipped with sufficient heat traps, either because the management believes the additional investment unwarranted, or because it is not sufficiently well informed as to the value of an air preheater. This boiler will have an exit gas temperature of about 525 deg. F., and assuming 70 per cent efficiency, will consume about 1800 lb. of 12,500 B.t.u. coal per hour. If the flue gas temperature is cut only 150 deg. to 375 deg. F., it will effect an increase of about 3.8 per cent in efficiency, or a saving of 100 lb. of coal per hr. With an annual load factor of 25 per cent this would mean a saving of

$$0.25 \times 8760 \times \frac{100}{2000} \times \$3.50 = \$383.25 \text{ yearly.}$$

Making due allowance for the cost of increased fan power and maintenance, a saving of this amount would enable the air heater to pay for itself in a reasonable time, and show a handsome profit over the remainder of its life. Larger units will show even better results. For example, a 1000-hp. boiler operating at 250 per cent of rating and 400 lb. pressure, will show an annual saving of over $4000 with a 300 deg. drop in exit gas temperature and a 33 per cent load factor.

Combustion Conditions Improved

So far it has been assumed that an air heater does nothing except reclaim some of the heat in the flue gas and return it to the furnace. But experience shows that it will do more than this. Preheated air vastly improves combustion conditions in the furnace, and makes possible reduced carbon losses and lower excess air. Particularly is this true of boilers having scanty or inadequate furnace volumes; so that in small or poorly designed power plants improvements of this type very often outweigh even the improvement occasioned by the reduction of the flue gas temperature, by making possible capacity increases of from 10 to 15 per cent. Quite often the purchase of a new boiler may be eliminated or indefinitely postponed by the addition of an air preheater.

The prime factors which must be considered in the efficient combustion of fuels in a furnace are time, temperature and turbulence. Preheated air unquestionably accelerates the ignition of any fuel, thus reducing the time element. Because of its own sensible heat, and the rapid, uniform and more complete combustion which it produces within the furnace, the temperature is increased. The increased temperature in addition to the greater molecular activity of preheated air over cold air causes more turbulence, and consequently a more thorough mixing of the gases of combustion, than would otherwise be the case. The more complete oxidation of the hydro-carbons in the fuel and the reduction of fly ash and soot in the stack gases eliminate, or at least considerably reduce, smoke. This is a factor of great importance in maintaining satisfactory public relations in many localities.

Cheaper Fuels Made Usable

Preheated air can be used to advantage with almost any type of fuel. Often plants which previously had been forced to use expensive coals, have obtained excellent results with the cheaper fuels, such as anthracite screenings, coke breeze, culm and petroleum coke, after having shifted to preheated air. Stoker manufacturers are building stokers that are able to utilize effectively higher air temperature than ever before.

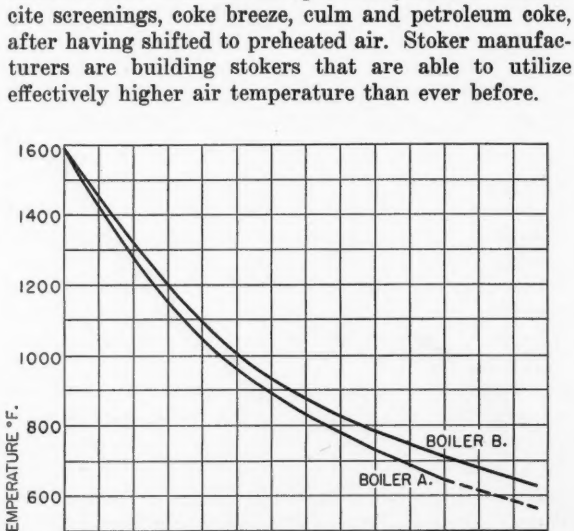


Fig. 1. Temperature drop of flue gases over last passes of boiler

In pulverized coal installations, preheated air is virtually a necessity. It is used for both primary air and for secondary air. Primary air is introduced through the burners with the coal with the triple purpose of increasing fluidity of the coal, evaporating the surface moisture of the coal and reducing the time required for ignition. The secondary air enters the furnace through ports adjacent to the burners or through the casing surrounding the burner. The purpose of the secondary air is to support the combustion of the fuel, and to promote the turbulence of the combustion gases in the furnace. Secondary air may be heated to high temperatures, the design of the burner usually being the limiting factor in this case. The temperature of the primary air, however, is definitely limited. If the air in the fuel pipe becomes too hot an undesirable advance coking of the coal takes place, and not infrequently the fuel will ignite in the pipe before it reaches the burner. To overcome this difficulty, cold "tempering" air is mixed with the hot air from the heater before it enters the pulverizer. Some air heater manufacturers even make the claim that preheated air is conducive to better pulverizer performance. This is highly problematical, but it is quite certain that preheated air of reasonable temperature will do nothing to impair pulverizer operation.

Fuel oil and natural gas burn better with preheated air. The effect of preheat in the case of these fuels is much the same as in the case of coal. It tends to shorten the flame, increase the rapidity of combustion, raise the flame temperature and promote more effective radiant heat absorption by the boiler. It must be remembered that in the sections of the country where these fuels are widely used they are relatively cheap, and a thorough study of plant conditions should be made in order to determine whether an air heater is economically advisable. Furnace temperatures and liberations are usually much higher with oil and gas than they are in the case of coal, and some thought must therefore be given to the possibility of increased refractory maintenance.

Preheated Air with By-product Fuels

Blast furnace gas is an almost valueless by-product of the smelting of iron ore. It has an extremely low calorific value and is greatly diluted by inert gases. Therefore it is necessary to raise large quantities of gas to the ignition point of the combustible materials. Combustion proceeds very slowly, heat release rates are low and inordinately large furnace volumes are required in order to get anything that will approximate decent boiler evaporations. At first glance, viewing the air preheater merely as a fuel saving device, anyone suggesting the addition of an air preheater to a unit burning this fuel might be suspected of something more than a slight tendency toward insanity. Actual installations, though, have proven that burning blast furnace gas with preheated air actually does speed up combustion and make higher heat release rates possible. This results in much smaller furnace requirements, which in turn permit smaller buildings with attendant reductions in initial investment cost. This makes it economically possible to use an otherwise almost worthless fuel.

Waste products from agricultural and lumbering industries are quite often used as fuel. These are always of an inferior grade, having low calorific values, and high moisture content, volatile matter and ash. Typical of this class of fuels are wet wood, sawdust and hogged fuel from saw mills and paper mills, and bagasse, which is the refuse from crushed sugar cane. The supply of these materials is often limited, and in order to obtain enough steam for process purposes, they are usually burned in conjunction with some other fuel, such as oil or coal. As in the case of blast furnace gas, the major problem is not to reduce fuel costs, but to obtain the required steaming capacity from the boilers with the quantity of waste products available.

The burning of wood presents a problem different from the burning of other fuels. Best results are obtained when a double furnace of some type is used. The initial distillation of the gases and ignition of the fuel take place in one section of the furnace which is screened or shielded in some manner from the heat absorbing surfaces, and the combustion of these gases is completed in the second and much larger section of the furnace. Care must be taken in the introduction of the necessary air into the furnace so as not to blow the fuel from the grates and leave large bare areas. Preheated air will sometimes increase the capacity of a given unit to such a point that the required steam can be produced without the aid of an auxillary or standby fuel.

Bagasse is burned in essentially the same manner as wood, although the furnace design may differ somewhat. Other fuels, such as tars and pitch from the manufacture of illuminating gas, refinery gas from the cracking and distillation of crude oil, liquors resulting from the "cooking" of wood pulp, peat and lignite are fuels which have been successfully burned with the aid of preheated air.

Preheated Air Temperature

The question of to what degree combustion air should be preheated, like most questions that arise in power plants, can be answered best by the stock reply, "that depends". The conditions existing in individual plants or proposed plant locations will determine the answer. Temperatures of from 500 to 600 deg. are not unusual, although they are by no means common. The higher temperatures are usually found in high pressure, high capacity pulverized coal units, where the large furnace volumes and effective water-cooling make it possible properly to utilize such degrees of preheat. Wood burning furnaces also can advantageously use highly preheated air, but generally high temperatures of preheat are not economically available in this type of furnace.

As a general rule, however, it is seldom advisable to preheat air above 350 to 400 deg. In smaller and older plants, preheating the air to 200 deg. may quite often be sufficient to warrant the installation of an air heater. The type of fuel used and its cost, the initial investment in equipment, the possibility of smaller boilers and furnaces, are all items that must be taken into consideration in the determination of the desirable air temperature. Too high furnace temperatures will

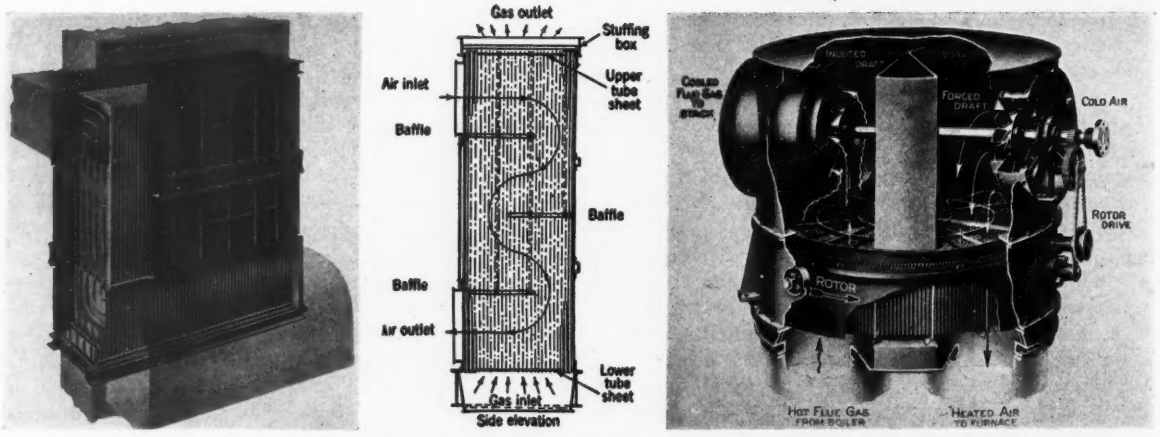


Fig. 2. Air preheaters: A—Plate type. B—Tubular type. C—Regenerative type

cause refractories to spall and disintegrate. Air that is too hot will cause trouble in stoker frames and castings. This all means increased maintenance costs.

Stokers Designed for Preheated Air

Realizing that preheated air has come to stay, and that pulverized fuel systems have tremendous advantages over the older types of stokers in utilizing it, the stoker manufacturers have worked and improved their designs to the point where temperatures as high as 600 deg. have been used on both underfeed and traveling grate stokers. Refractory manufacturers have also come forward with superior refractories which will stand up under the severe conditions imposed upon them by modern combustion methods. But superior products of any kind are always costly, and again the question of economic balance arises.

In attempting to achieve high degrees of preheat the end temperature of the gas leaving the heater must be given careful attention. The greater the gas temperature drop, the greater will be the increase in the efficiency and the temperature of the air. But all fuels give off corrosive gases to a greater or less degree. If the gas temperature at the exit is allowed to become too low, these gases will condense and dissolve in the moisture that forms from the water vapor in the stack gas. Acids will collect upon the heating elements, and the elements will have to be replaced in a short time. The dew point of these corrosive gases is difficult to predict, and the only safe procedure is to watch closely the gas exit side of the heating elements for signs of acid attack. The minimum safe temperature will depend upon the chemical composition of the fuel, and generally it should not be permitted to drop below 250 deg. Even this temperature may be cutting things rather closely. Corrosion may be avoided by partially or completely by-passing the air preheater at low loads, or by constructing the heating elements of acid resisting metals.

Types of Air Preheaters

There are three types of air preheaters commercially available, the regenerative, the plate and the tubular. These different types are described in detail in the January, 1938, issue of Power Plant Engineering. Each type has certain definite advantages peculiar to itself, and we may well take a leaf from the automobile industry and say, "Before you buy, look at all three".

In planning a new plant or in remodelling an old one, careful consideration should be given not only to the relative sizes of the various units but also to their proper correlation. In spite of what has been said previously about the ability of an air heater to increase capacities, one has yet to be built that will generate steam. This is the function of the boiler.

The boiler by all means should be large enough to generate the required steam, but it is inadvisable to try to attain high efficiencies with a boiler alone. Figure 1 shows the temperature drop of the flue gas over the last two passes of a typical bent tube boiler. Curve B is that of a boiler which is the same as that of Curve A, except that boiler B has about 25 per cent more heating surface, all of which is in the last two passes. That is, the two boilers are identical up to the entrance to the second pass. The dotted curve shows the temperature drop through an air preheater, the heating surface of which is just equal to the difference between the surface of B and A.

Boiler B has an exit gas temperature which is 20 deg. lower than that of A, but A in combination with the air heater has an exit gas temperature that is 70 deg. lower than B. Besides, the combination will supply to the furnace air at a temperature of about 180 deg. If then, boiler A is large enough to generate the required amount of steam, it would be wiser to increase the efficiency by adding the preheater rather than by providing additional boiler heating surface, especially as the cost of this additional surface is about three times as much as that of the air preheater. The air heater may also be made to take the place of the rear wall of the boiler setting, thus creating an additional saving. It is equally true that no attempt should be made to tack a preheater onto A with the hope that the boiler might thus be forced to do the same work as the larger boiler, B.

Air Heater or Economizer

A heat trap of some kind is valuable, indeed necessary, to most plants if power costs are to be kept down and competition met. Shall it be an economizer or an air preheater? In the large utility and industrial

plants where stage bleeding of the turbines is employed to heat the feedwater, economizers, in the ordinary sense of the word, are useless. The feed is heated to such a degree that the temperature differential between the feed and the exit gas is so small that it makes any worth while heat exchange between these two media an impossibility. So-called economizers are used in these plants, but they are really integral parts of the generating unit itself, rather than heat reclaiming devices used in conjunction with a boiler.

In plants where bleeding can not be economically employed, the choice between an economizer and an air preheater is often difficult to make. The economizer is undoubtedly the more effective of the two on the basis of heat absorbed per square foot of surface, the transfer rate of the economizer being three, four or even five times as large as that of the air heater. The absorbing power of the economizer, however, is limited by the difference between the saturation temperature of the boiler water and the temperature of the feedwater, and the cost on a square foot basis is about five times that of an air heater. An economizer is usually constructed with return bends or headers of some kind, is more accurately machined and has many joints which are a source of trouble. It is consequently more bothersome and expensive to maintain. Thus an air heater will cost about half as much as an economizer for a given amount of heat absorption.

It may well be in certain instances, that the amount of preheat obtainable exceeds the amount which can be effectively utilized. In that event, it may be advisable to use an economizer and an air heater in series. Combinations of this type will produce high efficiencies, especially at high ratings, but the draft losses through such a system may amount to from six to eight inches of water. Drafts of this magnitude require powerful fans, and particularly in those plants which purchase their electricity, the cost of fan operation may be prohibitive.

In burning low grade fuels, blast furnace gas for example, the weight of flue gas leaving the boiler is considerably greater than the weight of air necessary to support combustion. Obviously only a part of the waste gases can be used to preheat the incoming air. Here an economizer might be used in parallel with an air heater. In such a case careful design is necessary to proportion and distribute the heating surface in such manner that the resistance to the flow of gases that is offered by each unit will divide the gas between the units so as to obtain the optimum results.

In the foregoing, the virtues of preheated air have been extolled; the facts that preheated air can increase efficiencies and capacities, reduce maintenance and, in some cases, lower construction costs have been pointed out. But it must not be supposed that the air preheater is the panacea for all power plant problems. While an air heater might alleviate to some extent the ill effects of a poorly designed plant, it can never correct them. As yet, no one has succeeded in finding an acceptable substitute for good, sound engineering. An air preheater may be the answer to your problem as it has been to many others; but it should be remembered that one does not always have to go to a circus to find a white elephant or a boomerang.

Seal With Condensate

By J. B. COTTER

Supt. of Power Stations
Central Illinois Public Service Co.
Grand Tower, Ill.

AUTOMATICALLY sealing free atmosphere exhaust valves and ring type expansion joints between the turbine and condenser can be done satisfactorily by using condensate direct from the condenser hot well as shown in the sketch.

Condensate is admitted to the free atmosphere exhaust valve for sealing and then overflows into the turbine expansion joint seal basin. The seal water level in the expansion joint basin is maintained by the loop seal which directs the overflow back into the main condenser. Leakage past the expansion joint also drops back into the main condenser.

It should be noted that by using this method of sealing, the turbine water rate or condensate meter reading is not affected as the Venturi meter is installed in the condensate line beyond the cycle of the sealing condensate water. Using condensate for sealing also provides water of a favorable temperature. Another marked advantage is that the possibility of contaminating the condensate by any expansion joint leakage when using treated water for sealing is eliminated.

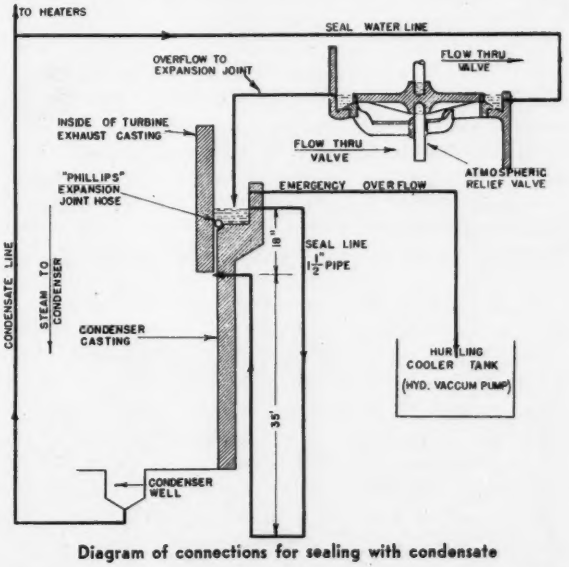


Diagram of connections for sealing with condensate

The emergency overflow line from turbine expansion joint seal basin, as shown in sketch, would be used only in unforeseen emergencies to prevent overflow on the floor or equipment. This line may be piped to discharge to any desired location.

In the particular installation, for which this article is written, it should be noted that the length of the loop seal is 35 ft. to prevent breaking the seal at a high vacuum or with any rise in seal water temperature. This method of sealing was installed on two 25,000 kw. turbo-generator units several months ago and has proven satisfactory in every way.

Installation tests and operating results of the new high pressure boiler fired by one of the first water-cooled stokers. This was part of a 5 yr. modernization program, of the municipal utilities at Austin, Minn., which cost $405,000 and saves annually $160,000.

Austin's High Pressure Boiler

By CARROLL L. ELLIOTT,
Superintendent
Board of W. E. G. & P. Comm.
Austin, Minn., and

JOSEPH V. EDESKUTY,*
Helmick, Edeskuty & Lutz
Minneapolis, Minn.

COMPLETE STUDIES outlining the need for additional steam generating capacity were presented in a report dated Oct. 7, 1935. This report, a portion of which is reproduced below, was based on an analysis of past and projected energy production, electric peak, steam production and peaks over a period dating back to 1905. An indication of the load growth is given in the caption of Fig. 2. This is a reproduction of the projected load covering a 20-yr. period from 1935 to 1955.

"The expected steam peak requirements are in excess of one of your two present boilers and both boilers would have to be used to satisfy these peaks. A forced shut down of one boiler would at such times result in the curtailment of the electric and steam heating service and this establishes the need for additional steam-generating equipment.

"On the basis of the results of our calculations, we recommend the installation of a steam generator capable of delivering 80,000 lb. of steam per hr.

"While you will probably continue to operate with your present steam conditions (namely 285 lb. ga. pressure) for some time, the new unit should be designed so that you may ultimately take advantage of the higher pressure and temperature for which the new 3500 kw. turbo-generator will give the best operating results.

"Both pulverized coal and stoker fired units, with and without heat recovery equipment, have been investigated and we have given consideration not only to installation costs, but also to operating costs and have determined these costs over a useful life of 20 yr. for each case.

"The conclusion reached is that the lowest overall operating cost can be obtained with the stoker fired unit of the most efficient type.

"The proposed new unit will supply the required capacity and will effect material fuel savings due to its better overall efficiency.

"The furnace should be so designed as to permit the use of natural gas fuel.

"If natural gas is to be used for at least part time, the necessary burners and oil standby equipment should be included. If the use of natural gas is not contemplated at this time, provision for future installation of burners should be made."

Average hourly, daily, monthly and annual heat balances were calculated and extended into the future.

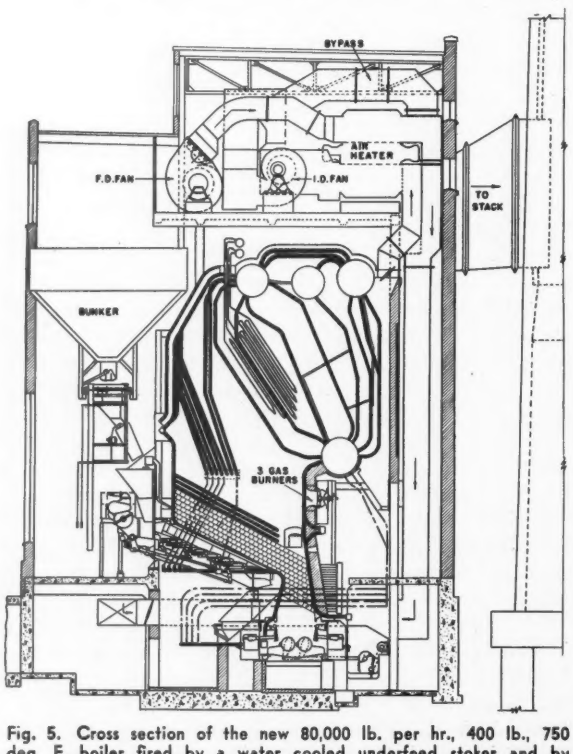


Fig. 5. Cross section of the new 80,000 lb. per hr., 400 lb., 750 deg. F. boiler fired by a water cooled underfeed stoker and by natural gas. Forced and induced draft fans and an air heater are located above the boiler

*Engineering work for this modernization program was handled by Ralph D. Thomas & Associates, Minneapolis, Minn., with whom Joseph V. Edeskuty, the project engineer, was formerly connected. An outline of the program as a whole with costs was given in the article "Austin Cuts Costs" on page 491 of the August issue. Turbine room changes, tests and power costs were covered in the article "Turbine Room Changes at Austin" on page 588 of the September issue.

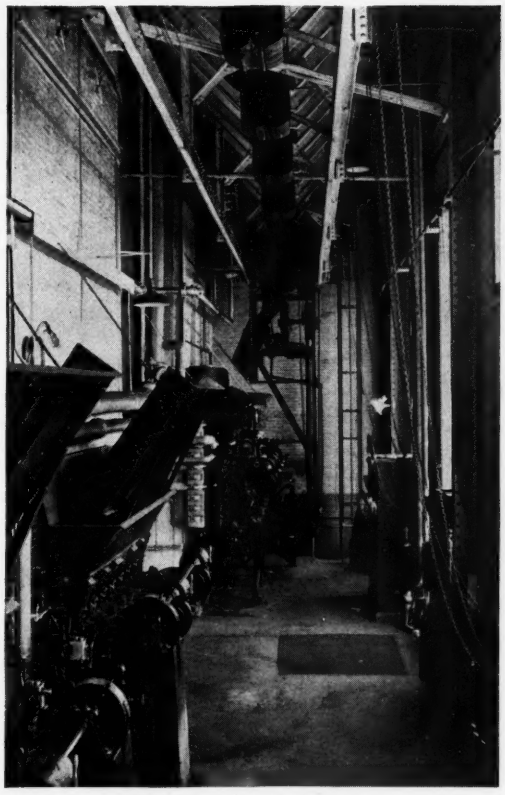


Fig. 6. The firing aisle with the new boiler and control panel in the background. The "man lift" or service elevator in the far corner facilitates the movement of operators from one level to the next

Average annual quantities for the year 1934-1935 are given in the caption of Fig. 4. Complete plans and specifications were then prepared and a contract entered into with the A. R. Robertson Co. of St. Paul. Minn., for the installation of the following equipment:

A Combustion Engineering V type bent tube boiler with welded drums and a boiler heating surface of 9580 sq. ft., a normal capacity of 50,000 lb. and a maximum capacity of 80,000 lb. of steam per hr. This boiler was designed for a maximum pressure of 425 lb. ga. and has 3690 sq. ft. of Elesco convection superheater surface, designed to give 283 deg. of superheat. The boiler has an internal steam washer, Crosby safety valves and pressure gages, Cochrane blow-off valves, Edward feed and check valves, Diamond floor level water column indicators and Diamond soot blowers with seven elements on the boiler proper and one element on the air heater. The air heater is an 11,350 sq. ft. Ljungstrom Regenerative unit, set above the boiler on the forced and induced draft fans platform.

The setting is Detrick sectionally supported, insulated and steel cased. The furnace walls are partly bare and partly armored with Combustion Engineering cast iron blocks with a total surface of 1112 sq. ft. In addition there is an effective heating surface of 448 sq. ft. from the stoker cooling tubes and 28 sq. ft. on the internal risers from the stoker tubes, giving a total heat absorbing area in the boiler and water walls of 11,168 sq. ft.

Firing equipment is designed for coal, gas or oil. Coal is burned on one of the first of the American Engineering Co. Taylor water-cooled stokers. This stoker has a grate area of 236 sq. ft., 8 retorts, and is operated by a Hele-Shaw drive with a steam turbine auxiliary drive. The stoker hopper is equipped with a coal agitator.

For burning gas and oil, there are installed on the back wall of the furnace, as shown by Fig. 2, three Peabody combination gas and oil burners with the necessary piping and valves. The burners are mounted on hinged doors and, when not in use, refractory plugs are inserted into the circular burner openings.

Fans

Both the forced and induced draft fans were supplied by the Buffalo Forge Co., the first with a capacity of 23,000 c.f.m. against 8 in. w.g., is driven by a 60 hp. General Electric turbine. The second, with a capacity of 43,000 c.f.m. against 4.5 w.g., is driven by a 80 hp. General Electric turbine. All air ducts for coal and gas firing are insulated and the breeching and dampers are arranged so that the boiler may be operated with or without the air heater and with or without the induced draft fan.. A bypass is arranged around the air heater to give control of temperature and avoid condensation and corrosion in the breeching.

A complete system of Hagan automatic combustion control is provided with the necessary operating instruments control equipment and pressure gages mounted on one operating panel. This panel includes a Hays CO_2 recorder, Cochrane flow meter and flue gas and air temperature recorders.

The coal handling system was remodeled. The old apron feeder and elevator within the building were removed and new Fairfield Engineering Co. feeders and an elevator were installed outside of the boiler room building. The existing Beaumont weigh larry was adapted to serve the higher stoker hopper of the new unit and an Allen-Sherman-Hoff sluice system, which includes a vacuum cleaning system, was added for handling the ash from the stoker clinker.

At the time when the new unit was under consideration, natural gas was available at a cost which promised economic operation. It was, however, ex-

Table IV. Summary of boiler tests, giving the expected performance and the test results. Test 1 was made burning coal; Test No. 2 was made burning gas

	TEST NO. 1 - COAL		TEST NO. 2 - GAS	
	Expected Performance	Test Results	Expected Performance	Test Results
Capacity, lb. per hr.	28,876 Eq.	28,939 Act.	33,760 Eq.	32,319 Act.
Efficiency, per cent	84.98	85.13	82.3	85.24
Steam pres., lb.ga.	300	281	300	280
Steam temp., deg. F.	660	644	645	744
Feedwater temp., deg. F.	210	205	210	210
CO_2, per cent boiler outlet	14.5	12.1	9.5	9.42
Flue gas temp., boiler outlet, deg. F.	489	463	482	473
Flue gas temp., heater outlet, deg. F.	479	260	228	227
Air temp. into heater, deg. F.	80	98.5	80	98.3
Air temp. to stoker	444	334.7		
Air temp. to gas burners			436	418.3
Draft loss, boiler and superheater, in. w.g.	0.18	0.09	0.18	0.08
Draft loss, air heater and ducts, in. w.g.	0.60	0.71	0.53	0.90
Total draft loss, in. w.g.	0.78	0.80	0.71	0.98

pected that with the continuing increase of domestic consumption, the time would come when gas would be available at low costs for certain months only and that coal would have to be burned for the remainder of the year. The new unit was to be designed to supply the entire demand, and with the varying load and small requirement over a considerable portion of the operating day, the analysis indicated that the stoker rather than pulverized fuel would give the lowest operating costs. The design of a unit for successfully and efficiently burning natural gas and oil and a wide range of coals on a stoker, separately or in combination, necessarily involved numerous problems.

That all these problems, together with the difficulties of building the unit into a confined space, were successfully solved is a source of great satisfaction to all parties concerned. The fact that natural gas was to be burned alone influenced the selection of the stoker equipment. A new departure in the art of stoker design, namely the water-cooled underfeed stoker, was then for the first time available and was taken advantage of.

Natural gas burners were designed to burn also fuel oil and were installed with the necessary gas reducing metering station and with fuel oil storage tanks, pumps, etc. The ability to burn oil was deemed necessary in order to prevent interruption of service in the event of failures of the supply when burning natural gas. In this case oil, being the most expensive fuel, will be used only until a sufficient coal fuel bed can be built up.

Water walls and cooling tubes include some unusual features. The tuyere cooling tubes extend over the length of the stoker, rise on the inside of the front wall and are connected to a header on the outside of the setting above the stoker hopper. From this header the front water wall tubes reenter the furnace and are folded in an ingenious manner, to provide expansion for the rather inflexible stoker cooling tubes. The side water walls are inclined and armored with caston blocks. The rear water wall extends over the entire width of the furnace and is partly armored. Some of the tubes of this wall are curved and others are deflected to provide three openings for the gas burners.

Major problems connected with the construction of the unit were:

a. The foundation. The left front boiler column is located directly over the footing slab of a building and coal bunker column. As this footing was already loaded to capacity, the boiler foundations had to be cantilevered over this area in order to avoid a possible settlement of the bunker column.

b. Insufficient head room in the basement. This made the excavation of a portion of it necessary with underpinning of present boiler, building columns, walls, etc.

c. Fan platforms. Forced and induced draft fans and the air heater are located on a concrete platform, which is carried on the boiler supporting steel. To accommodate this equipment and the complicated duct work, the roof was raised approximately 10 ft.

d. Ash handling. The new ash handling sluicing system delivers the cinders on the river bank. To make this possible an underground pump chamber, which also houses the oil transfer pumps, was constructed. From this chamber, a reinforced concrete tunnel, 6 ft. wide and 7 ft. high was projected, passing under the present tracks of the Chicago and Great Western Railway to a subway entrance. This tunnel is used for the ash conveyor pipe and all other water, steam, and oil piping. The cinders are delivered in a large box. They are of small size, thoroughly washed and the plant has no difficulty in disposing of them to consumers, as fast as they are produced. The oil storage tanks are located on the river bank.

Problems of Operation

After the new unit was placed in operation, some of the retort cooling tubes developed burns and leaks. This was due to a lack of circulation and was remedied by a complete redesign of a part of the stoker-cooling system. The horizontal portion of the risers was given a slight inclination, and the number of risers was increased. Whereas the risers formerly entered the furnace near the top, they are now collected in a small header on each side of the setting and from this header they enter the furnace just above the inclined water wall and in this manner create the necessary head on the retort tubes for proper circulation. Thermocouples were buried in the retort tubes at critical locations and test readings on these under various operating conditions indicated that no further trouble was to be expected from this source. The next difficulty occurred in the fuel distribution when burning certain grades of coal. The shape of the pushers was changed and their number increased before this difficulty was overcome.

Another problem was the excessive superheat when burning natural gas. After exhaustive tests by recording furnace temperatures, CO_2 readings in furnace, superheater space, etc., and by measuring the air supply to the burners, a baffle was installed on the second row of boiler tubes in order to shield the superheater from the direct action of the gas flame. This has brought the steam temperatures within permissible limits.

All fuels can now be burnt successfully. Gas alone can be used by burning out the coal fuel bed, after stopping the stoker, to provide a protective bed of ashes and by filling the stoker hopper with some incombustible material. It is, however, expected that, when natural gas is available at an advantageous figure, a small amount of coal will be supplied to the stoker in order to prevent fires in the bunker and in the stoker hopper.

Guarantees and Test Results

As with the turbine, these tests were made to give the actual operating results, a summary of the two final acceptance tests are given in Table IV. The coal used for Test 1 was generally of poor quality. It contained large quantities of fines with heavy foreign material. The latter fact was substantiated by the appearance of the fuel bed and the refuse. Occasional feeding of coarser coal would produce burned out areas in the fuel bed and it was difficult to maintain uniform CO_2 readings, which varied from 9 to 14.5 per cent with an average of 12.1 per cent in a 24 hr. test.

In Test 2 the coal fuel bed was completely burned out and coal was used as the main fuel. Only sufficient coal was delivered to the furnace to prevent fire in the stoker hopper. The stoker was given one revolution per hour, was fed 115 lb. or a total of 690 lb. for the 6 hr. test. All air to the plenum chamber and to the clinker grinder was shut off.

Comparative Fuel Costs

In the first test Franklin County 1½ in. raw screenings running 11,800 B.t.u. per lb. were used. The contract price for this coal is $1.63 and the freight $3.00, making the total cost delivered $4.63 per ton. To this is added, in cents per pound: unloading labor, 0.0660; depreciation of coal and ash handling equipment, 0.0533; power for coal handling, 0.0045; power for ash handling, 0.0150; stoker maintenance, 0.0112. This gives a total cost per ton of $4.78. Boiler heat absorption per 1000 lb. of steam from and at 212 deg. is 970,200 B.t.u., representing, with an overall boiler efficiency of 84 per cent, a heat liberation of 1,155,000 B.t.u. Added to this for sootblowing is 180 lb. of steam per t. of coal. This represents 239,400 B.t.u., or 14,250 B.t.u. per 1000 lb. F. & A. With 84 per cent boiler efficiency, the total heat liberation would then be 1,169,250 B.t.u. per 1000 lb. This requires 99.09 lb. of coal at a cost of 23.69 cents per 1000 lb. of steam from and at 212 deg., or 28.44 cents per 1000 lb. of steam actual evaporation.

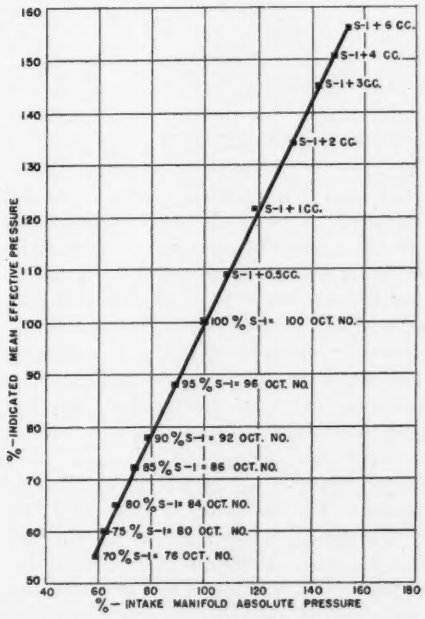
When burning natural gas with a boiler efficiency of 83 per cent, the necessary liberation per 1000 lb. of steam from and at is 1,168,915 B.t.u., representing 1,168.915 cu. ft. of 1000 B.t.u. gas. At a gas cost of 18 cents per 1000 cu. ft., the fuel cost is 21.04 cents per 1000 lb. from and at, or 26.32 cents per 1000 lb. of actual operation.

Later a Southern Illinois washed carbon, running 12,172 B.t.u. per lb. was burned. This coal cost $1.50 at the mine and carried a freight charge of $3.15 giving a total delivered cost of $4.65. Less an allowance of 10 per cent for moisture and plus plant costs of 0.15 cts. per t. gives a total cost in the hopper of $4.34. Coal required per 1000 lb. from and at was 94.889 lb., giving a coal cost of 20.59 cents per 1000 lb. from and at or 24.72 cents per 1000 lb. actual evaporation. These figures do not represent test results but actual performance including all operating losses, sootblowing, etc., over a period of two weeks. Other coals such as Northern Illinois and Southern Indiana will be tried in the near future. Results so far indicate that certain coals can at present prices successfully compete with natural gas.

It has become standard practice with some concerns to mark on their blueprints the magnitude and direction of maximum nominal stress to which the casting is subjected in service. These stress analyses are of value in that they make possible the choice of a foundry practice which will produce the optimum properties in those sections subjected to maximum stress in service. Static breakdown tests can be made on castings through the section or sections involved, thus checking the effectiveness of the foundry methods used.—W. G. Harvey before the S.A.E.

Fuels and Engine Outputs

FOR SOME YEARS, internal combustion engine fuel research has been carried on by the Cooperative Fuel Research Committee (C.F.R.) and at the June 1938 meeting of the S.A.E., H. K. Cummings reported on the correlation of knock ratings by different methods with full scale service tests for a number of aviation fuels. Some fuels were found to be correctly evaluated by the motor method, with others the A.S.T.M. method is satisfactory, while with still others it may under or over rate several octane numbers. Modifications of the A.S.T.M. method is under way to give results more in accordance with the data presented in the report.


% – INDICATED MEAN EFFECTIVE PRESSURE
% – INTAKE MANIFOLD ABSOLUTE PRESSURE
S-1 + 6 CC.
S-1 + 4 CC.
S-1 + 3CC.
S-1 + 2 CC.
S-1 + 1CC.
S-1 + 0.5CC.
100 % S-1 = 100 OCT. NO.
95 % S-1 = 96 OCT. NO.
90 % S-1 = 92 OCT. NO.
85 % S-1 = 88 OCT. NO.
80 % S-1 = 84 OCT. NO.
75 % S-1 = 80 OCT. NO.
70 % S-1 = 76 OCT. NO.

The work is concerned primarily with aviation fuels and is of no particular interest for general industrial service conditions. One phase, however, dealt with the effect of the fuel octane number on engine output and is shown graphically by the chart. C.F.R. fuels S-1 and M-1 were the reference fuels used in the tests. The octane scale has not been defined beyond 100, but tetraethyl lead in C.F.R. reference fuel S-1 is used as a tentative standard for evaluating the knock characteristics for fuels of 100 or over which are now of considerable interest in the aviation field.

Details of an inspection and repair schedule to insure a thorough inspection and suggestions for maintenance standardization. This is an abstract of an A.S.M.E. paper, part of which, with detailed maintenance report forms, appeared in the October issue under the same title.

Diesel Engine Maintenance

By E. R. SPICER

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WITH A WELL TRAINED competent personnel and adequate records it is possible to perfect, systematize, and standardize maintenance activities. Where there are large numbers of engines to be maintained in widely separated plants the matter of systematization becomes paramount. It is necessary to outline certain policies and practices as a guide to those field men who are in charge of actual work.

Intelligently directed uniform procedure in this regard tends to eliminate many of the bad practices so often encountered. That is to say without the use of specific instructions, each individual follows his own judgment. One man may, for instance, in the light of his limited experience, feel that a certain type of engine should operate for a period of 20,000 hr. without a thorough inspection, while the real economical operating period may be only half that figure. It is only through the study of a great number of authentic records that one is able to formulate and issue workable instructions. With this in mind it is well to repeat that in so far as possible detailed instructions should be issued to unify general maintenance activities and policies.

The following are a few of the general practices that can and should be made standard for a given type of equipment: Hours of operation between general inspection; when crank shaft alinment should be checked; period of operation between valve grinding and reconditioning; when to indicate and check over entire combustion; information relative to operating speeds, injection pressures, starting procedures, etc.

In some organizations instructions relative to the above and other general topics are issued in booklet form to all concerned.

Many of the more specific details can be outlined and placed in the hands of field men. For instance, a systematic inspection schedule has been found to be very effective.

Table III is offered as an example of what can be done along this line. This outline is one used by an organization having Diesel engines scattered over a large territory. It will be noted that this outline is sufficiently general to be applicable to the majority of heavy duty low speed engines when intelligently applied. On the other hand it is specific enough to insure a thorough inspection.

It is quite conceivable that without some such outline many parts would not receive proper attention. As stated above the judgment of machinists and other men vary too widely to expect uniform inspection without some sort of a guide.

There are many routine procedures that can be standardized. We might mention as another example the detailed instructions on the tightening of connecting rod bolts. This particular task is one by which the skeptic may prove for himself the importance and value of standardized instruction. A variation of 100 per cent in initial stress has been found when identical bolts were tightened by two competent mechanics.

In addition to specific instructions regarding general policies and routine procedure many forms of mechanical repairs can be standardized. The necessity

of unifying repair methods is obvious when the interchangeability of parts is considered. For example, occasionally it becomes necessary to true up engine piston pins. If each pin is considered separately it is evident that the sizes become so numerous that the stocking of piston pin bearings becomes hopelessly involved. On the contrary, however, if and when piston pins for a given make of engine are rehabilitated the diameter is reduced to one of two or three predetermined under sizes, then the matter of stocking of pin bearings becomes relatively simple. In every progressive maintenance organization there should, therefore, be a catalogue of approved sizes to guide those in charge of rehabilitating machine parts.

Figure 1, with a brief discussion of the problems involved, will serve to further clarify this point. Two of the parts on an air injection Diesel most subjected to wear are the spray valve needle and seat. In this particular instance the seats are kept in condition by reaming and grinding the seating surfaces as conditions require. The continued wear on both seat and valve needle has the accumulated effect of shortening the needle. The general construction of the fuel valve and operating mechanism is such that this shortening has a detrimental effect on fuel injection.

With the company, whose maintenance work has been the subject of our study, necessary corrections were first accomplished by each field man making repairs as he deemed advisable. The inevitable result was, of course, a vast number of methods. Obviously the interchangeability factor was nil. Even in the same plant the method of repair was so varied that the repairs to fuel valves became a problem of endless confusion. The task of standardization was then referred to a maintenance engineer.

After a study of records, material, and existing procedure, he offered the standard repair as indicated in detail by Fig. 1. The adherence to the dimensions and other instructions on this sheet will insure the proper spray valve needle lengths without the distortion of any other adjustment. A small stock of the three lengthus of tips in each plant enables the machinists to keep this particular part of the engine in constant repair.

Table III. Outline for machinists to follow in the overhaul of any single unit

This outline is to be considered as one of inspection procedure. There is no attempt to outline repair procedure. Occasionally suggestions of adjustment methods are made to insure complete and accurate inspection data. It is sufficiently general to be adapted to most any type of heavy duty Diesel engines. Thus, items will appear on this schedule that are not a part of certain engines. For instance, headings indicating compressor repair will not be considered when working on solid injection engines. It then becomes necessary for the machinist to apply the outline to each particular unit. The sequence of procedure need not follow that indicated in this outline. Circumstances and conditions makes it necessary for the machinist to arrange the order of work for each inspection job.

When dismantling machinery, arrange removed parts in an orderly manner at convenient points. Be sure that all parts are set on boards or timbers to prevent scarring floor paint. Give careful attention to the thorough cleaning of the various parts. A solution of Oakite or other approved cleaning solution such as gasoline, kerosine, or lye water may be used. As a safety measure, grease or vinegar may be used to protect skin from the lye or othe caustic solution. Never use dirty or greasy tools; they contribute to accidents of all kinds.

The machinist should be very careful to record all observations, measurements, and complete details of abnormal conditions, such as cracked bearings, unusual wear, etc., and place this information on the maintenance report in clear-cut, concise language. It is very important that the machinist refer to and study previous maintenance reports, and records before starting an overhaul.

I. GENERAL
1. Inspection of engine before overhaul, while running or shut down as conditions require.
   A. Indicate—When possible or advisable indicate and study compression and firing pressures, noting any other irregularities that may appear on the diagrams.
   B. Check pressures on water, lube oil, and the three stages of air compressor.
   C. Inspect all pressure relief valves.
   D. Check valve timing and lifts.
   E. Observe governor action.
   F. Check fuel pump for leaks in plungers, packing, etc.
   G. Attempt to locate abnormal noises.
   H. Note any condition not in keeping with good practice.

II. REMOVAL AND INSPECTION OF PARTS
1. Remove all rocker arms and valve mechanism.
   A. Examine for flat spots and wear on rollers, pins, bushings, etc.
   B. Note wear on tappets.
   C. Check fulcrum pins and bushings for wear.
2. Remove valves from head and recondition.
   A. Clean and grind until all pits have disappeared. In case valves or seats are warped or badly pitted, it may be necessary to send to machine shop for refacing.
   B. Inspect valve springs for length and tension.
   C. Fuel valve should be carefully inspected to determine wear and general condition.
   D. Inspect all moving parts including valve stems, valve stem bushings, guides, lock washers, etc.
3. Remove main cylinder heads after determining head clearance with lead or copper pipe.
   A. Where convenient, remove exhaust and intake headers; if not convenient, then block in place.
   B. Clean head. If necessary, use an approved scale remover. As a safety measure, a solution of two pounds of baking soda to ten gallons of water may be used to prevent acid burns.
   C. Remove all clean-out plates and plugs to facilitate cleaning.
   D. Examine carefully for defects such as cracks, leakage and bad seats.
   E. Replace clean-out plugs and plates.
4. Wash engine jackets and exhaust header.
   A. If scale is present use approved scale remover.
5. Remove crank case doors and casings over cam shaft drives.
6. Wash out crank case with kerosine, hot water, or steam.
   A. Break connections on end of engine to facilitate cleaning. Be sure to replae as soon as cleaning is completed.
7. Block connecting rod bearings.
   A. Measure bolt length before relieving strain on nut.
   B. Relieve strain on nut and remeasure bolt length.
   C. Tighten set screws for holding connecting rod bolts in place and remove nuts.
   D. Compare measurements made in "A" above with previous measurement when bolts were installed. Compare measurement in "B" with original bolt length.
8. Pull pistons.
   A. Remove rings and note carefully general conditions and indication of blowby.
   B. Clean and inspect pistons inside and out for cracks, scores or other defects.
   C. Remove piston pins, measure and note dimensions in planes perpendicular and parallel to piston pin. A cradle arrangement may be used in this work to prevent knocking the piston out of round.
   E. Thoroughly clean oil hole in connecting rod and insert cork until installed.
   F. Install piston pins in pistons.
   G. Measure piston skirt.
      1. Use wood block and sledge to adjust piston skirt dimensions to where it is approximately 0.00015 per in. of diam. smaller parallel to the pin than perpendicular to same.
   H. Where oil cooled pistons are used, break out oil cooling header as much as possible and clean.
9. Remove connecting rod bearings from crank case.
   A. Inspect carefully for cracks, loose babbitt or other defects.
   B. Inspect connecting rod bolts very carefully. Note bearing surface under head and evidence of damage.
   C. Suspend connecting rod bolts from string (non-metallic) and sound for cracks.
10. Measure with micrometers the distance between crank webs.
   A. Take measurements on all cranks in the four quarter positions.
11. Remove main bearing caps (Outboard bearing is considered as main bearing).
   A. Inspect for cracks, loose babbitt, and evidence of heavy bearing areas.
   B. Inspect journals for light and dark spots.
12. Take bridge gauge readings on all main bearings.
   A. If bridge gauge is not at hand, spot frame directly above journal and measure distance between spot and shaft.
   B. Press shaft into shell with either clamp or jack and take second bridge gauge reading.
   C. In case deflection in item 10 is more than .002" in any one position, remeasure the distance between crank webs at the point in question while shaft is clamped in bearing.
   D. Examine crank shaft for cracks. (Paint with alcohol and chalk.)
   E. Bridge gauge reading of main bearing before and after pressing down should never vary more than 0.002 in.

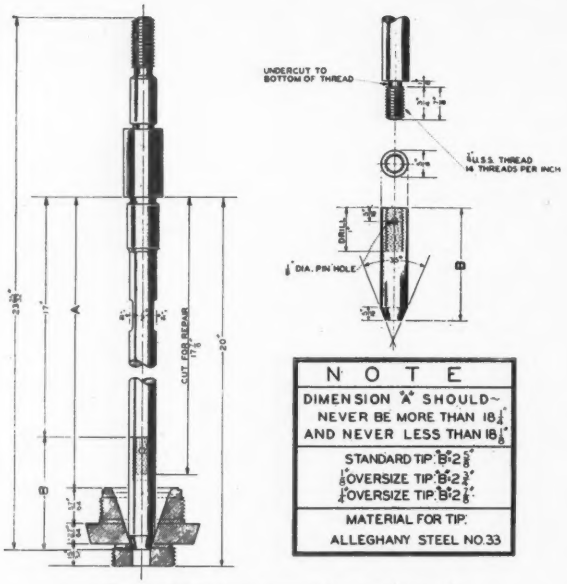
UNDERCUT TO BOTTOM OF THREAD
U.S.S. THREAD 14 THREADS PER INCH
DRILL
DIA. PIN HOLE
CUT FOR REPAIR
NOTE
DIMENSION "A" SHOULD NEVER BE MORE THAN 18 1/4" AND NEVER LESS THAN 18 1/8"
STANDARD TIP 1 5/8" - 2 5/8"
1/4" OVERSIZE TIP 1 5/8" - 2 3/4"
1/4" OVERSIZE TIP 1 5/8" - 2 7/8"
MATERIAL FOR TIP: ALLEGHANY STEEL NO. 33

Fig. 1. Method of spray valve needle repair

13. With approved shafting level determine position of all main journals.
    A. Determine pitch to foot and direction of slope.
14. Roll main bearing shells out of socket, inspect for defects, and evidence of relative pressures.
    A. Compare thickness if necessary.
15. From numbers 11 to 14 above determine the cause of crankshaft misalignment, if any.
    A. A crude sketch of crankshaft showing journal levels and web distances will aid materially in locating the cause of misalignment.
    B. Leave crankshaft with not more than 0.002 in. difference in measurements between crank webs in any two diametrically opposite positions.
16. Replace main bearing caps and lower shells giving proper clearance after all oil passages have been thoroughly cleaned.
    A. Clean all oil passages and piping with air, steam or any other approved method at hand.
    B. Take leads on bearings with original shims. From this information determine amount of shims to be removed to insure proper clearance.
    C. The rule generally followed for main bearing clearance is to allow 0.0005 in. clearance per in. of diam. and to this amount add 0.002 in.; thus a 10 in. shaft will require 0.007 in. clearance.
    D. Use precaution to insure the pulling down of cap evenly and squarely with the main frame.
    E. Check crank shaft end thrust and as far as possible, adjust to manufacturer's recommendations.
17. Inspect vertical shaft and shaft drive, or other cam shaft drives.
    A. Remove all housing necessary.
    B. Inspect and adjust bearing clearances and thrust.
    C. Note gear clearance and wear.
    D. Inspect timing chain and pinion for tension, wear and other defects.
18. Examine cam shaft.
    A. Adjust bearing clearance and thrust.
    B. See that all cams are tight and in proper position.
    C. Examine cams for excessive wear.
19. Check fuel pump and fuel piping.
    A. Check all moving parts such as pins, bushings, crossheads, links, straps, eccentris, etc., for exessive wear defects and adjustments.
    B. Check and repair all pump, check, and try valves, removing valve bodies when necessary.
    C. Reset governing valves to manufacturer's recommendations.
    D. Be sure that all valves have the required spring tention and lift.
20. Inspection of governors.
    A. Dismantle the governor and completely overhaul same.
    B. Note all joints and bearing races as well as all other moving parts for breakage, wear, and lost motion.
    C. See that all nuts, keys, etc., are in place and tight.
    D. Make sure that all parts work freely and show no signs of stress.
21. Replace housings on cam shaft driving mechanism.
22. Examine lubricating oil pump.
    A. Dismantle lubricating oil pump. Observe general conditions and compare with requirements for satisfactory operation.
    B. Note bearing and shaft condition.
    C. Inspect and renew packing.
    D. Note condition and repair driving mechanism.
    E. Completely dismantle, clean, and repair relief or bypass valve.
23. Measure liner diameter with inside micrometers.
    A. Take measurement both parallel and perpendicular to crank pin.
    B. Measurements in (A) to be taken near center of liner above oil hole, about one inch from top of ring travel, using standard locating iron for determining exact position.
    C. If abnormal conditions appear, take other measurements.
    D. Operate force feed lubricator by hand and thoroughly check all lube lines from lubricator to cylinder. Give special attention to the lubricator plugs in cylinder lines.
24. Replace connecting rod bearings.
    A. Properly place leads and original shims so that clearance can be determined later.
    B. Again carefully inspect connecting rod bolts and replace, securing same in position with set screws provided for this purpose.
    C. Replace required compression shims.
25. Prepare piston and install.
    A. Fit rings in liner and determine end gap, which should be 0.005 in. per in. of diameter of the ring.
    B. Determine width and condition of ring grooves in piston.
    C. Install rings making sure of proper side clearance.
    D. Thoroughly oil liner, piston, and spacer rings; insert assembly.
26. Adjust connecting rod bearing.
    A. With piston and connecting rod assemble in place, tighten bearing bolts to insure pinching of lead wire to actual bearing clearance.
    B. Remove lead wire to determine original clearance and adjust shim thickness to give required clearance.
    C. Tighten bolts in accordance with standardization sheet for the particular engine.
    D. Operate hand lubricating oil pump and check to see that oil runs freely through all bearings. Check oil piping for leaks.
27. Replace cylinder heads.
    A. See that all contact parts are clean and gaskets annealed.
    B. Tighten all head bolts gradually and with equal tension.
    C. Check head clearance.
28. Replace valves in head.
    A. Make sure that copper gaskets are annealed and cleaned.
    B. Clean seats and all contacting surfaces. Make sure that all seats are free from all foreign substances.
    C. Tighten valve bolts evenly, moderately tight, allow for expansion. Use a wrench without a cheater for this work.
29. Replace rocker arms.
    A. Give all valves recommended roller clearance.
30. Remove all compressor valves.
    A. Clean and grind.
    B. Check valve lifts where necessary.
    C. Carefully examine all parts for excessive lube oil.
31. Measure head clearance on all stages.
    A. Use lead for this purpose.
32. Remove head and pull compressor piston.
    A. Clean and observe carbon deposit.
    B. Inspect rings for wear and defects, replacing those no longer serviceable.
    C. Examine and adjust piston pin bearing.
    D. Thoroughly examine compressor liners, taking measurements with micrometer whenever advisable.
    E. Replace compressor piston.
    F. Examine and adjust connecting rod bearing making proper allowance for head clearance.
    G. Inspect all air piping, and air bottles and, when necessary, clean with steam, air, or any other means at hand to insure thorough cleaning. Inspect intercoolers and clean as required using suitable solutions for boiling out deposits. Sharp tools must not be used for this purpose.
33. Replace compressor head and valves.
34. Set timing on all valves.
    A. With a bevel protractor or tram, check opening and closing of inlet and exhaust valves on at least one cylinder.
    B. Use air and bevel protractor or tram to set opening and closing of fuel valves.
    C. Thoroughly inspect crank case for rags, blocks, and other loose objects, jointly with station engineer on duty.
    D. Replace crankcase doors.
35. Check all foundation and frame bolts.
36. Examine flywheel bolts and see that nuts are tight.
37. Prepare engine for starting in cooperation with the engineer on duty.
    A. Operate mechanical lubricator by hand to insure oil supply to pistons.
    B. Bar engine over several complete revolutions and spot.
    C. Check air pressure in starting and injection bottles.
    D. See that wrenches and all other material are out of the way of moving parts on the entire unit.
    E. Take other necessary steps common to starting the engine.
38 Start Engine.
    A. Operating engineer should start unit. The machinists should not touch gate valves, switches or other apparatus incident to plant operation unless the engineer is present.
    B. Operator should stay near throttle for first few minutes.
    C. Engine should be shut down, doors removed, and inspection made within 10 min. after starting.
    D. Inspect 30 min. after the first stop. Then run for 2 hr. at full load and inspect. Then run for 4 hr. at full load and inspect. If the inspection is satisfactory to the engineer and mechanic, the engine should be placed in the line for a 24 hr. run at full load.

Diesel Lubrication

To show the importance of cooperative research between the engine manufacturer and oil refiner, the author told the A.S.M.E. of tests demonstrating the effectiveness of specially prepared lubricants. Some of the general remarks regarding the influence of the agents added to the lubricant, and the new filter problem involved follow.

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TO A CONSIDERABLE EXTENT the problem of high speed Diesel lubrication involves a study of the cause and effect of carbon and binder forming deposits. In this it is quite in order to place ring sticking first.

Sticking of inlet valves in the high-speed Diesel engine is largely a problem of dirt and dust contaminations and may be induced by air-cleaner deficiencies. The sticking of exhaust valves is related to fuels and to lubricants, and to a combination of both. The carbonaceous materials in the exhaust gases find their way into the clearance of stem and bushing, and retard valve seating. The amount of these carbonaceous deposits from combustion gases varies with the fuels and the degree of completion of the combustion process at the time of valve opening.

The indirect effect from fuel deposition travels up the valve stem from below, whereas the influence from lubricants operates downward from above. When using straight mineral oils, it is customary to cut the supply of lubricants to the valve stem to the minimum, to restrict the formation of gummy deposits on the valve stem. With compounded types of lubricant, however, a copious supply is essential to make use of the solvent power of the oil in assimilating the stem deposits.

Filters

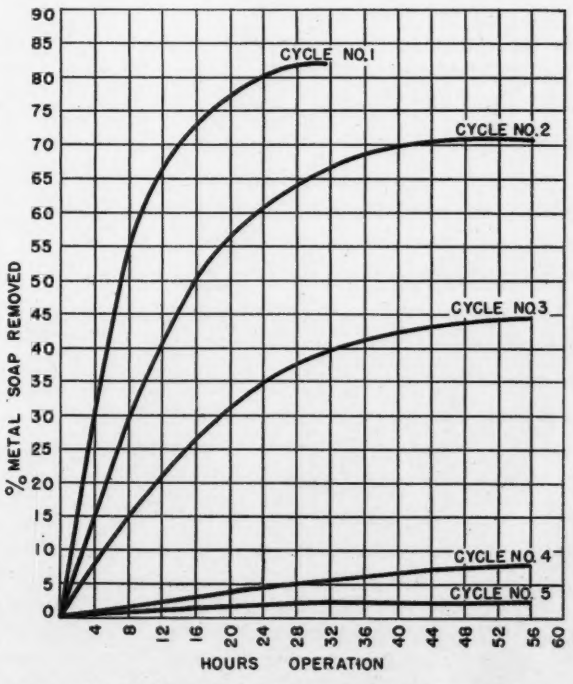
The subject of filters is one subject to considerable difference of opinion. The function of a filter is primarily one of removing injurious materials from the lubricating-oil system. What constitutes injurious materials appears subject to wide interpretation. A good filter, however, should effectively eliminate abrasives, metal particles and water, and, insure that the accumulations remain permanently separated and unable to reenter the flow of the system.

Filters can be quite advantageous in removing sludges and crankcase depositions. They do not, however, efficiently remove ring-sticking binders. Their use may postpone ring sticking somewhat, but the most deleterious binder materials are developed in the zone of the piston-ring belt quite remote from the sphere of activity of the filter. Filter depositions vary considerably with different types of lubricants.

Many believe that the lubricating-oil filter should be a refining system, while others approve the practice of systematic oil changes because of the resulting desirable solvent action of new oil. The operating benefits derived from the use of selected additives to base oils are of great economic importance. Not only does their use improve Diesel-engine lubricants in resistance to ring sticking, but advantages are also derived in decreased cylinder and ring wear, reduced blow-by, depression of sludges, increased film strength, and effective flushing and cleansing. As these desirable qualities are conducive to lowered maintenance costs, their preservation is paramount.

Some filters of the adsorbent type not only remove the impurities accumulated in the lubricating-oil system but also the desired additives of compounded oils. Not only is there a decidedly growing tendency toward the use of additives for Diesel operation, but they are also being used in motor oils for such purposes as corrosion inhibition, pour-point depression, and others.

These ingredients, designed to yield specific operating virtues, are removed by many of the clays and earths in use in adsorbent-type filters. The curves show the percentage of metal soap removed from the oil by such filter. Cycle 1 represents the activity of removal of a new filter on the first oil filling. After 60 hr. of engine operation, the crankcase oil was changed and the influence of the filter on this new batch of oil is shown in cycle 2. It is evident that the ability of the filter to remove soaps continues for five cycles or a total of 300 hr. of engine operation. The ingredients which were designed to provide improved operating qualities were removed from performing their function.



Agents added to improve the performance of Diesel engine lubricants may be inadvertently removed by certain types of filters as shown by these curves of metal soap removed by an absorbent type filter

Electron Tubes—

PART XXXI

By A. W. KRAMER

Thyratron Exciter For 15,000 kv-a. Synchronous Condenser at the Suburban station of the Scranton Electric Co.

THUS FAR in considering the problems of voltage regulation by means of electron tubes, we have described two systems, one based upon the principle of the condenser discharge, whch really amounts to the accurate measurement of the voltage of a condenser and the other based upon the amplified relation between the grid bias voltage and the plate current of the three electrode high vacuum tube.

Before we leave this subject, we will direct attention to still another method, a method using a photoelectric element and one that is applicable to the control of other values besides voltage. Fundamentally this method is almost absurdly simple and while not as accurate or rapid as the other methods described it is exceedingy useful and it has been applied in a number of commercial control devices.

This method is based upon the simple expedient of boring a small hole in a voltmeter or any other meter at a point in the scale where some control function is to come into play and then mounting a phototube behind the hole so that the pointer will intercept a beam of light passing through the hole into the photocell.

As has already been pointed out, all control functions are really extensions of the field of measurement. Any measuring instrument such as a voltmeter or ammeter or thermometer can act as a controller provided it can be made to exert sufficient torque to move the mechanism. For example, if the voltmeter connected to the d.c. circuit in Fig. 1 could exert sufficient torque to operate the field rheostat of the small generator through the linkage system shown, it would serve as a voltage regulator as well as a voltmeter. If the voltage of the circuit tends to increase, more resistance will be cut into the shunt field circuit and the terminal voltage of the generator will drop.

Where voltage changes are large such a system could be made to work, but of course a standard voltmeter would not be used, as such devices are far too delicate to move any linkage system however delicately constructed. Sometimes meters are provided with very light contacts which are closed or opened by the movement of the pointer, but beyond that the use of measuring instruments for control purposes is usually not feasible.

This, however, is where the almost inconceivable delicacy of photocell control comes into play, for, as pointed out in a preceding chapter, the photoelectric principle permits the use of an imponderable beam of light as a connecting link—not only as a connecting link but as an inertialess, frictionless operating lever. By drilling a hole in the scale of a meter, any pointer, however delicately designed or balanced, can be made to intercept a beam of light entering a photocell. Through suitable vacuum tube amplifiers the photocell can then in turn be made to actuate controlling elements which will bring the meter pointer back to its normal position, and thus, at the same time, restore the normal state of the circuit.

An application of this scheme has been made in the control of a 250-v. d.c. generator. The general idea of this control is shown in Fig. 2. As will be noted, the plate impedance of the final amplifier tube takes the place of the usual field rheostat. This impedance is a function of the grid bias of the tube and this in turn is controlled by the photocell. The latter is mounted behind the hole in the voltmeter so that when the voltmeter needle uncovers the aperature the full illumination falls on the photocell. As the system is arranged, this will cause maximum bias to be applied to the amplifier tube in the generator field circuit and under these conditions the resistance of the generator field circuit will also be at a maximum.

Principles and Applications

Although many electron tube applications are complicated others are almost absurdly simple. One of those described here is of the latter class and it consists merely in boring a hole through the face of a meter and letting a light shine through it—at least that is the basic idea. In another application described here the principle of regulation is combined with that of power supply in the design of a thyratron exciter for a 15,000 kv-a. synchronous condenser.

The terminal thus will be reduced to its lowest value. On the other hand, when the aperture is covered by the indicator the reverse condition will prevail; the grid bias and the plate resistance of the amplifier tube will be at a minimum and the generator voltage will be at its highest value. The change in voltage permitted will vary between the values represented by the width of the aperature in the meter dial. If the width of the slit represents the distance the indicator moves for a change of 1 volt, the output of the generator will vary plus or minus 0.5 volt of the specified value.

A modification of this hole-in-meter principle has been utilized in a photoelectric frequency regulator developed by Westinghouse. In this case a frequency meter is the heart of the device, but instead of using the indicator to intercept a beam of light, a small mirror is mounted on the end of the indicator, as shown in Fig. 3. By means of a simple optical system and two sources of light, this mirror reflects light into either of two photocells. When the frequency of the circuit to which the meter is connected is low, the mirror turns and reflects a beam of light into one photocell; if the frequency is high, the light is reflected into another photocell. In either case, the cell involved will close a relay which will apply proper corrective action to the governor of the prime mover driving the generator. Normally, when the frequency is at the correct value the reflected light from the indicator mirror is intercepted by the fixed mirror mounted immediately below the meter. Other refinements consist of a slotted rotating disc driven by a small motor to prevent hunting. The speed of this disc is such that the slot lets light through every two seconds. Thus, the photocells are permitted to apply corrective action for a limited interval of time only. The shape of the slot is such, however, that the greater the deflection of the mirror the longer will be the duration of the corrective action. The system, therefore, brings the frequency back to normal at a rate which is roughly proportional to the departure from normal and does not overshoot.

These two applications of the phototube, one in a voltage regulator and the other in a frequency regulator, are presented not so much to describe these particular devices as to indicate how the phototube has extended the usefulness of instruments beyond the range of measurement into the field of control. It will be obvious that innumerable adaptations of this scheme are possible. Within this scheme anything

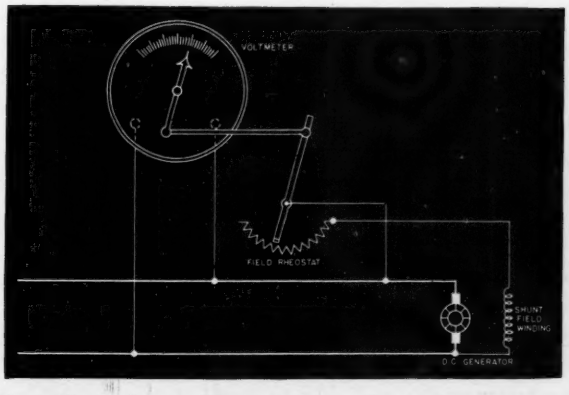


Fig. 1. Showing how a voltmeter might be used as a voltage regulator, provided it could exert sufficient torque to operate the mechanical system shown

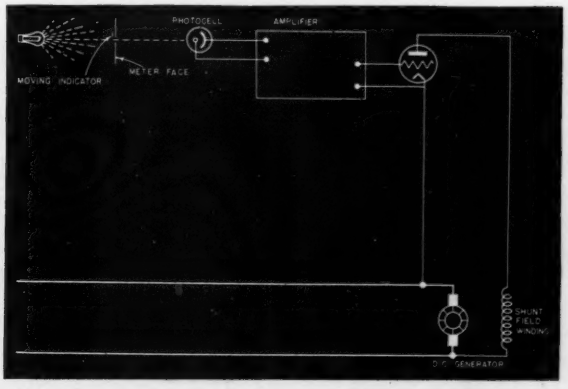


Fig. 2. Basic idea involved in the control of a 250-v. d.c. generator by means of the hole-in-meter principle. In this case the final amplifier tube serves as the field rheostat

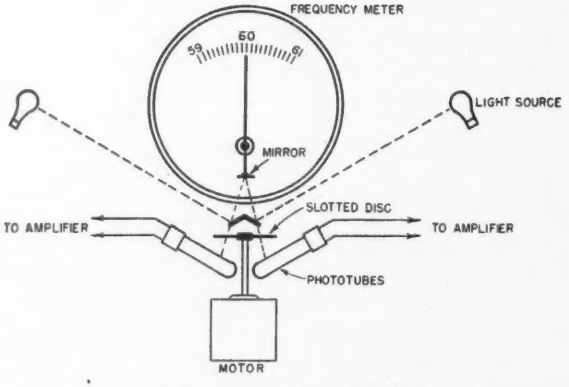


Fig. 3. Diagram showing the principle of the photoelectric frequency regulator developed by Westinghouse

that moves a pointer, a column of mercury or water, a rotating disc, etc., becomes a controlling agency.

In the case of the photocell voltage regulator described above, it will be noted that the last amplifier tube must be capable of carrying the entire field current of the generator. This, therefore, limits the application of this system to very small generators, unless some form of grid controlled gas filled tube could be substituted for the high vacuum tubes used. Such tubes are capable of handling much greater power.

The use of such gas filled tubes introduces the possibility of not only controlling the excitation but of actually supplying the excitation for a generator or motor. While no large scale application of such a system has been made on a generator, one has been in operation on a 15,000 kv-a. synchronous condenser since 1933. This machine is installed at the suburban plant of the Scranton Electric Co., a subsidiary of the American Gas & Electric Service Corp. The details of this interesting installation were described in the Electrical World for June 22, 1935, in an article by Philip Sporn.

In this case the entire excitation current of some 600 amperes is obtained from six FG-53 air-cooled thyratons. The usual rotating exciters are entirely displaced, all moving parts of any kind eliminated. The exciter is essentially a rectifier, the output voltage of which is controlled by the a.c. line voltage.

The arrangement used is shown in Fig. 4. The actual excitation power is supplied from the 4000 v., 3 phase bus through the excitation transformer at the right, while the control of this excitation power is effected through the grid transformer and the copper-oxide rectifiers at the left. The control voltage is derived from the 3-phase potential transformers also supplied from the 4000 v. 3 phase bus.

Each phase voltage is rectified separately by the copper-oxide rectifiers and the three rectified voltages so obtained are added to provide a d.c. potential which is applied to the thyrite bridge. The output of the bridge obtained as a voltage difference between points "a" and "b" is applied to the grid of the 841 triode amplifier. The plate current through this tube flowing through resister R_1 develops a variable bias voltage which is applied to the FG-57 and controls the point in the cycle when the FG-57 fires.

Considering the FG-57 thyratron control stage, the resultant grid voltage on this tube depends on (1) a fixed d.c. bias obtained across R_4 and R_2, (2) a fixed a.c. bias obtained from the grid transformer, lagging 120 deg. behind the anode potential and (3) the variable d.c. bias, already referred to, obtained across R_1 from the output circuit of the 841 triode amplifier.

As soon as the FG-57 control thyratron fires, a d.c. voltage is developed across R_3 which is applied to the grid of the corresponding FG-53 power tube, causing it to fire, the latter tube being normally biased to cut-off by its 110 v. fixed grid bias. After the FG-53 power tube has fired the voltage applied across the FG-57 is limited to the arc drop of the FG-53 power tube (about 20 v) and by the resistor R_5, consequently the current through the control tube is reduced to practically zero. This leaves practically only the 100 v. bias voltage on the grid of the FG-53 and so when the plate voltage passes through zero, the tube cuts off.

In the circuit diagram only one of the six phase circuits is shown; but the other five phases are similarly equipped with FG-57 and FG-53 tubes, all of

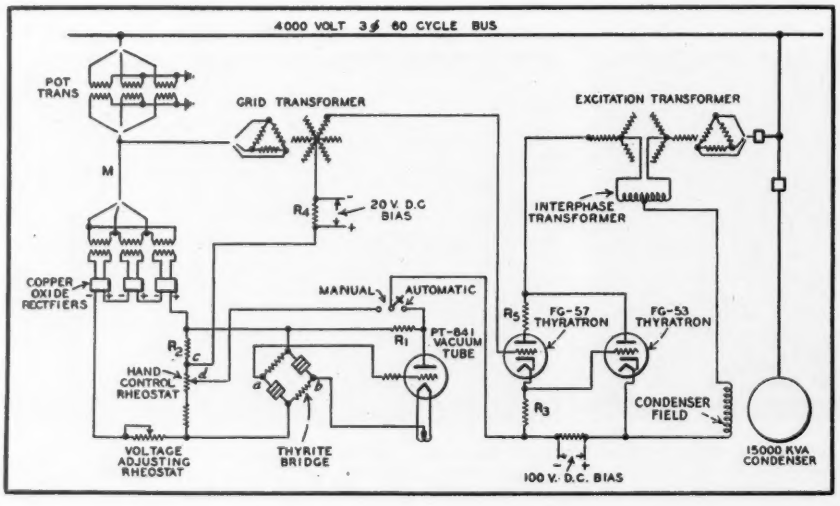


Fig. 4. Simplified diagram of the thyratron regulator-exciter for the 15,000 kv-a. synchronous condenser installed at the Suburban plant of the Scranton Electric Co.

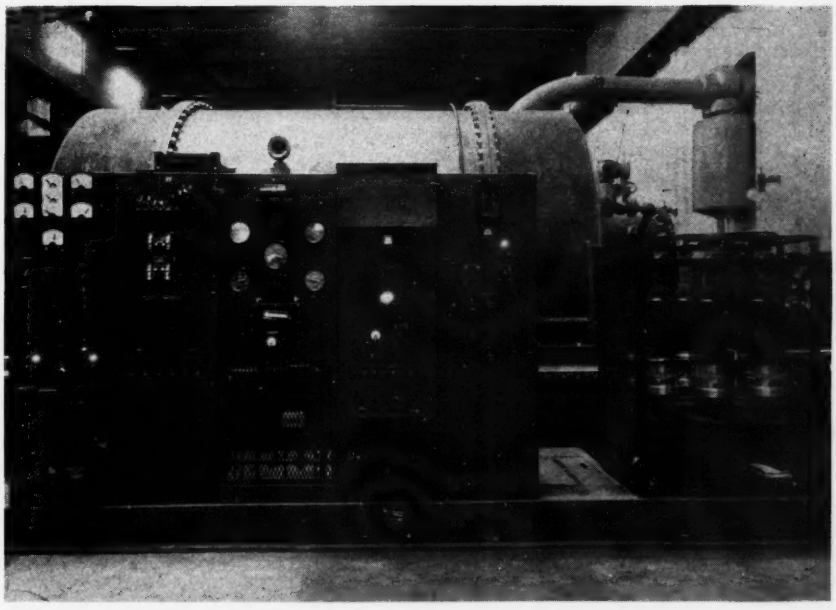


Fig. 5. Another view of the thyratron exciter showing the six FG-53 power thyratrons in the screened enclosure at the right. The two 841 tubes are located near the top of the right hand panel and the six FG-57s are installed in the metal enclosure at the top of the adjacent panel.

which, however, are controlled by the same 841 tube. Thus a six phase exciter is provided whose output is regulated by the a.c. line voltage.

In the case under consideration this vacuum tube exciter is applied to a synchronous condenser, but there is no reason why such a system cannot be applied to a generator if it should prove desirable. The system has rapid response, in the installation tests less than one cycle was required to bring the field voltage to maximum under short circuit conditions. The maximum field voltage applied under these conditions was about 300 v., the normal being 116 v. at 15,000 kv-a. leading. The sensitivity of the system is such that a change from 3000 kv-a. lagging to 18,000 kv-a. leading resulted in a change in the regulated voltage of less than one per cent.

During operation of this thyratron excited condenser it was found that any two of the FG-53 power tubes could be put out of service without overloading the remaining tubes, or affecting the smoothness of the field current even when the latter had a value of 600 amp. With all three tubes of one Y out of service, the field current of 300 amp. did not overload the remaining tubes.

Although this installation is used in actual service, it is of course to a certain degree experimental. It is not necessarily a question of whether this thyratron tube installation is better than an ordinary rotating exciter system. The important thing is that here is a new way of doing something we have done by other means, and that it combines two functions in one.

The further development of a system such as this lies in the perfection of the tubes used and the reduction of their costs. At the present time large power tubes are expensive and their life somewhat uncertain, but there is no reason to believe that with greater production their cost will not be lowered nor that with continued use and experience their life will not be lengthened. Tubes, carrying 600 amperes peak anode current at 1500 v. are after all somewhat different from the small glass affairs we use in our radio receivers and it is to be expected that their development will entail time and effort. Only within the past few weeks there was reported a development involving a modification of the 866 rectifier tube and in which this comparatively small glass tube was enabled to carry 35 kw. 0.5 amp. at 70 kv.

Editor's Note: For the photographs of the thyratron exciter used in this article we are indebted to Philip Sporn, vice-president of the American Gas & Electric Service Corp.

Modern Turbines

Continued from from page 695.

watt hour of power. In the absence of specific data for the boiler and auxiliary apparatus it may be assumed that with modern equipment the overall plant heat rate will be in the magnitude of 25 per cent to 30 per cent greater than the turbine heat rate.

Is it not apparent that the heat rate is a much better measure of steam turbine performance than the steam rate?

In the next article feed-water heating will be discussed, with some consideration of theory, but with special emphasis on the results which may be obtained. Simple charts will be given for approximating the efficiency gain with one, two, or three stages of extraction for feed-water heating. By the use of the charts in this and the succeeding article any engineer should be able to approximate the effect of changes in the design steam conditions of a power plant and the advantages which will accrue from the use of feed-water heaters.

ACCORDING to a noted psychologist, most people's brains act like a partial sit-down strike. Only 50 hp. being used, with 100 hp. of installed mental capacity. How's *your* mental load factor?

Steel Tank Mercury Arc Rectifiers

During the past two years the theory and mode of operation of all kinds of electronic rectifiers have been presented in these columns by Power Plant Engineering in its series of articles on the principles and applications of electron tubes. This article will, therefore, be confined mainly to a description of one type of steel tank mercury arc rectifier and a brief summary of the economic advantages realized in a few typical installations, as well as to a statement of some of the practical advantages obtainable by the use of grid control.

By OTTO KELLER

Rectifier Division
Allis-Chalmers Mfg. Co., Milwaukee, Wis.

THE action of a mercury arc rectifier depends upon the fact that electrons can be easily made to leave mercury at relatively low temperatures and with a comparatively weak electric field, but will not readily come out of material such as iron or carbon. Thus, if two wires from an a.c. supply are connected, respectively, to a small pool of mercury and to a clean piece of iron or carbon, both being located in a vacuum, enormous numbers of electrons will leave the mercury and go over to the other, solid, electrode during that portion of the alternating current cycle when the voltage of the iron or carbon is more positive than that of the mercury, but only a negligibly small number of electrons will leave the solid electrode and pass over to the mercury during that portion of the cycle when the mercury is at a more positive voltage than the solid electrode. Actually, the arc will not start unless a very high voltage is applied between the electrodes or unless a small arc is struck at the surface of the mercury cathode. For this purpose a small movable electrode called the ignition anode, or an igniter, partially immersed in the mercury, may conveniently be used. The spot on the surface of the mercury from which the electrons are emitted becomes intensely heated, and moves erratically over the mercury surface. The heat generated serves to vaporize some of the mercury, which then reduces the electrical resistance of the space between the anodes and the cathode. To assure an adequate supply of mercury vapor, one or more auxiliary anodes are provided.

A simplified cross-section of a rectifier of this type is shown in Fig. 1. The anode is shown with air-cooled radiating fins in solid lines, and with a water-filled radiator in dotted lines. The air-cooled design is used for low-current units in which heat losses are comparatively easily dissipated, and the water-cooled design, operating on the thermal syphon principle, is used for rectifiers of higher current rating.

The rectifier consists of a double-walled steel tank, the cooling water entering at the bottom, first cooling the cathode, then passing, in turn, through the hollow side walls, the top plate, sometimes called the anode plate, and finally the condensing dome.

The anodes are located in shields or "sleeves," and beneath each anode is located its associated control grid, which is provided with a separate lead and vacuum-tight bushing for the application of the control voltage. The vacuum seals between the anode and grid lead-ins and the anode plate of the rectifier are provided with an additional protection in the form of a thin layer of mercury. The level of this mercury in the seal assembly is made visible by means of a small gage glass, and in case a seal should develop a leak its location is instantly recognizable by the sinking of the level in its gage glass, so that the bolts may be tightened and the difficulty remedied at once.

The ignition device consists of a solenoid-operated plunger which dips into the mercury cathode to start the arc. The arc is maintained during periods of low load by one or more excitation anodes which are so located that the distance between them and the cathode is considerably less than the distance between the main anodes and the cathode. Consequently, a small amount of auxiliary power will serve to keep the cathode spot "alive."

If an igniter, which dips into the cathode mercury, is used to start the arc, a current impulse is given to it once every cycle. This requires an auxiliary source of such impulses, but obviates the necessity of having an excitation arc burning constantly.

For Low Power Applications

By suitably connecting the windings of the transformer used with the rectifier, the number of phases can be increased from 3 to 6 or even 12, which will result in a smoother d.c. output voltage and current. A rectifier may, however, have 12 or 18 anodes even when it is used only for 6-phase rectification, as in some cases it is preferable to have two or even three sets of parallel secondary windings on the rectifier transformer, and consequently two or three anodes may operate in parallel simultaneously, thus reducing the heating of the individual anodes.

An igniter-type rectifier, on the other hand, consists of one, two, three, six, or more, individual tanks, each containing one anode, one cathode, and one igniter. This type of rectifier has also been described and its operation explained in a previous issue.[1]

Since the magnitude of the voltage drop in the arc of a rectifier is practically independent of the voltage being carried, and is a direct measure of the rectifier losses, it follows that the efficiency of a rectifier will improve as the output voltage is increased. If the arc drop is, for instance, 20 v., the losses of a 250-v. rectifier on that account will be 8 per cent, while those of a 25,000-v. rectifier, such as comes into consideration for plate power supply for radio stations, will be only 0.08 per cent, or, in other words, the efficiency of such a rectifier tank, alone, is 99.92 per cent.

The losses in the transformer and auxiliaries will of course make the overall efficiency of the whole installation less than this value. However, while voltages of this order involve relatively large losses, compared to the loss in the rectifier itself, at medium and low voltages the losses in the transformer are only a small part of the total.

Although large numbers of mercury arc rectifiers are used for electric railway systems, yet applications of mercury-arc rectifiers are not limited to supplying high-voltage direct current, even though the majority of the 500,000 kw. or more of rectifiers installed in this country are operated at 500 v. and higher for electric railway power supply. Their high efficiency at high voltages and ability to carry high momentary overloads are responsible for their general adoption for railway service. There are, however, many industrial applications at 500 and 250 v. direct current where mercury arc rectifiers are economical, and where their other desirable characteristics make them ideal converting equipment.

In recent years the conversion of many metropolitan power supply systems from direct current to alternating current has created a field for low power conversion equipment to supply elevators and other low power drives in office and small industrial buildings located in the territory formerly served with direct current. For such applications both the glass tube and the steel tank mercury arc rectifier are well suited, as the cost of installing such equipment is usually less than the cost of changing over all the motor drives to a.c. operation.

The first steel tank rectifier installation of this type was placed in operation some 3 yr. ago. The set is rated at 150 kw. at 250 v. d.c. and supplies power for elevators, miscellaneous motors and lighting of a large Philadelphia warehouse. The rectifier replaced two old 200-kw. steam-engine driven d.c. generators which were abandoned in favor of purchased a.c. power. The boiler plant, which previous to the rectifier installation supplied power and steam, and which was operated throughout the year, is now required only during the heating season, and is no longer used to supply power.

The rectifier is cooled by fresh water and is provided with semi-automatic control, i.e., the vacuum is automatically controlled. An operator is available daily during an 8 hr. shift and six days per week. The rest of the day, nights, Sundays and holidays, the rectifier is operated without an attendant.

This unit is installed in the basement of the warehouse and no changes in floor or wall structure were required.

A schematic diagram of connections of such a set is shown in Fig. 2. (For the sake of simplicity, the grids are not shown in this figure.)

The no-load (idling) losses of a motor-generator set with a rating of 150 kw. are approximately 15 kw.,

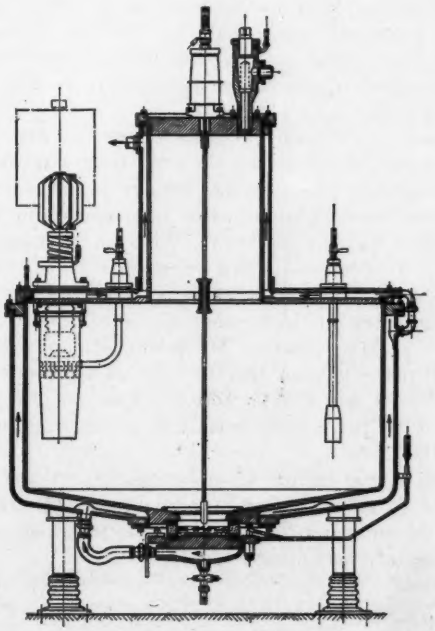


Fig. 1. A simplified cross section of a steel tank rectifier

[1]Variable Speed Motor Control with Electronic Power Tubes. By S. R. Durand. Page 476. August 1936.

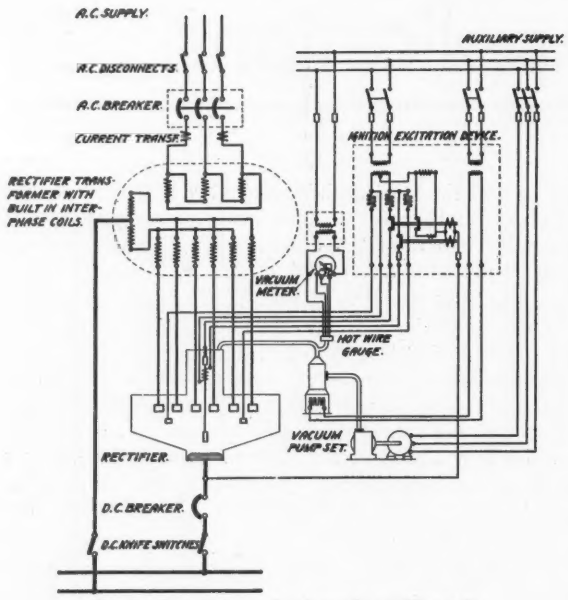


Fig. 2. Connections of a 6 anode rectifier unit

while those of the rectifier unit described are only about 3.5 kw., or in other words, less than one-quarter those of a motor-generator set. This fact is the principal reason why rectifiers will save considerable power in installations where the converting equipment has to operate for long periods at very light loads, as, for instance, nights and week-ends. This is the case in this particular installation and is a condition which prevails in general in converting plants supplying buildings.

To illustrate the economies obtainable with a rectifier, Fig. 3 shows curves giving the overall efficiencies, as a function of the percentage of load, of such a 150 kw., 250-v. rectifier, including all auxiliaries, as well as for a similarly rated synchronous motor-generator set, both being supplied from a 2300 v., 60-cycle, 3-phase network. The spread between the efficiency curves of the two types of equipment is particularly evident at the lighter loads.

Based on efficiency curves shown in Fig. 3, and the average station load observed over several years' operation, the yearly power savings of the rectifier installation as compared with a motor-generator set was computed to 82,400 kw-hr. With an average power rate of 1c per kw-hr. this represents a yearly saving of $824.00. From this has to be deducted the cost of cooling water for the rectifier which, at the usual water rate of $1.00 per 1000 cu. ft., amounts to approximately $78.00 per year, and therefore leaves a net power saving of $824, less $78, or $746.00. This amount, capitalized at 10 per cent corresponds to an investment of $7,460,00.

The power factors of the rectifier mentioned above, and of a similarly rated induction motor-generator set, both measured on the 2300 volt a.c. terminals, are approximately as follows:

Load	¼	½	¾	Full-load
Power factor of Rectifier in %	93.0	93.3	94.0	93.5
Power factor of M-G in %	66	78	86	90

It follows from these figures that with the load as prevailing in this installation an average power factor of well over 90 per cent is obtained by the rectifier, while with an induction motor-generator set it is estimated that the average power factor would be less than 80 per cent. With the use of a synchronous motor-generator set, a higher average power factor could naturally be secured, but it is doubtful whether under the prevailing load conditions a synchronous motor-generator set operating more than 70 per cent of the time unattended would show a better average power factor than the rectifier.

Another rectifier installation, rated at 265 kw., 265 v. d.c., also in an office building, where it is used mainly for supplying power to elevators, for which direct current is preferred, showed an average annual expense for repairs and supplies of $50 per yr.

Similarly, direct current is generally preferred due to its greater ease of control, for mining operations, and the suitability of mercury arc rectifiers for supplying d.c. power to mine haulage systems is exemplified by two successful installations. In one of these a 300 kw., 550-v. automatic rectifier has for ten years supplied d.c. power to the haulage system of a coal mine in West Virginia.

During the years in which accurate records were kept, the average yearly maintenance cost of this rectifier was $79.60, against $198.20 for automatic motor-generator sets, and $255.50 for automatic converters, all operated on the same power system and serving mines.

In spite of the fact that this rectifier was one of the first installed in this country, at no time during the ten years' operation was the assistance of a factory representative required for its maintenance. This rectifier replaced a 300-kw. synchronous motor generator and raised the overall substation efficiency from 50 to 85 per cent. The above records check closely with the records of over 300,000 kw. of rectifiers installed in railway substations and industrial plants throughout the country.

About a year ago, a similar automatic 550-v. rectifier unit, but rated at 600 kw., was placed in service in a Pennsylvania coal mine for supplying d.c. power to the haulage system of that mine. This unit also has given very satisfactory results. The saving of power, due especially to the high efficiency at fractional loads, has been at the rate of more than 25 per cent of the first cost of the rectifier per year.

Somewhat over a year ago, for the first time in the history of the American Steel Industry, a mercury arc power rectifier was installed to supply direct current to a steel mill.

This rectifier unit, which is rated 1000 kw., at 250-v., is installed in a steel mill located in the Chicago District. It converts 2300-v., 3-phase, 60-cycle a.c. power to 250-v. direct current, which is supplied to wire drawing stands, cranes, lifting magnets, etc. Figure 5 shows this installation.

The installation costs of mercury arc rectifiers are low on account of the absence of heavy rotating masses, so that no special foundations are required. Furthermore, the cost of the starting gear needed for a mercury arc rectifier is much smaller than in the

case of rotating conversion equipment. These facts already compensate, at least in part, for the somewhat higher equipment cost of mercury arc rectifiers in the lower voltage classes, around 250 v., which averages approximately 20 per cent more than rotating conversion equipment of the same rating. The large savings in power and maintenance costs exemplified in this article would in any case be more than ample to compensate, in a very short period of time, for any differential in the combined equipment and installation costs of rectifiers as compared with rotating converters.

Electrically-Energized Grids

In more recent rectifier installations simple and convenient control of the output voltage and current is an added feature made possible by the use of electrostatically energized grids installed directly in the path of the arc, a short distance below each anode.

The principles according to which these grids function have also been clearly explained in previous articles in this publication, but for convenience they may be briefly restated below. In a rectifier having only one or more anodes and a cathode, each anode will attract electrons and thus carry current only as long as it is at the highest positive potential with respect to the other anodes. By placing electrically energized grids a short distance below the anodes, an electric field can be set up, which may be either positive or negative with respect to the anodes. This field will then either assist the flow of electrons to the anodes or will prevent that flow altogether.

In a high-vacuum device such as the average radio tube, the grid can also effect a gradual regulation of the number of electrons flowing to the anodes, but in the presence of an ionized vapor, such as that of mercury, the grid cannot exert a smooth regulation over the flow of electrons, but can only either assist it or prevent it. The only way a grid can regulate the output voltage, and, therefore, also the current, in a rectifier of this type is by preventing the flow of electrons to an anode for a desired portion of that alternating-current half cycle during which the anode is positive, and then releasing the flow of electrons. As a result the average voltage delivered by the rectifier over a period of one cycle,—and therefore, its continuous output voltage,—is reduced as some function of the length of time during which the flow of electrons is delayed to each anode during each cycle.

Grid-control has passed the experimental stage and has been fully developed commercially so that the majority of all metal tank rectifiers now being installed are equipped with this improvement.

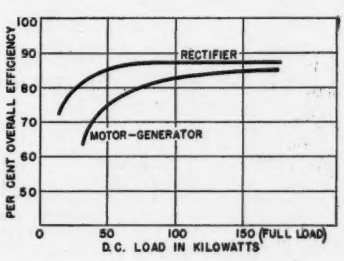


Fig. 3. Overall conversion efficiency of 150 kw., 250-v. mercury arc rectifier with auxiliaries and of a similarly rated induction motor-generator set (2300 v. motor)

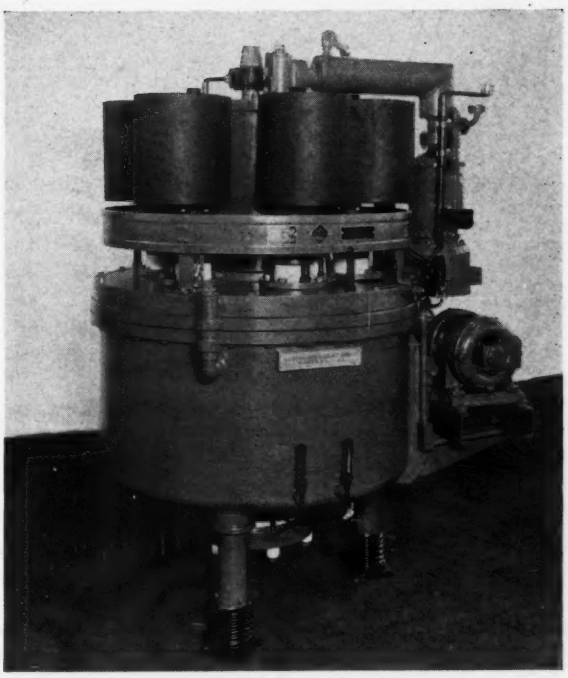


Fig. 4. A grid controlled mercury arc rectifier with built-on evacuating equipment, rating 600 kw. 500 v. d.c.

Since the power required by the grids to control the mercury arc of even the largest rectifiers amounts to only a few hundred watts or, roughly, one ten-thousandth of the amount of power passing through the rectifier, the grid-control equipment is inexpensive and light in weight. Moreover, the rating of this apparatus is independent of the rating of the rectifier or of the magnitude of the supply voltage.

There is a slight lowering of the power factor when grid-control regulation is used to compensate for the natural voltage rise of rectifiers at low loads or a.c. and d.c. line drops, but even at only one-quarter load, the power factor reduction due to grid-control is usually less than 4 per cent, which is generally acceptable.

On the other hand, if the rectifier is operated continuously with its voltage reduced more than 15 per cent by means of the control grids, its operation may become uneconomical on account of the lowered power factor; also, the increased ripple, due to the large reduction in output voltage, may become undesirable. In most applications, however, operation at greatly reduced voltages is not required, except for starting or for temporary periods of operation at very light loads, so that the reduced power factor is not objectionable.

If a wide range of voltage regulation is required only at intervals the reduction in efficiency and power factor are unimportant. If the voltage has to be varied within wide limits at frequent intervals, high power factor and efficiency may be maintained by combining a coarse regulation by a few taps of large steps on the transformer with a fine regulation between those taps by means of grids.

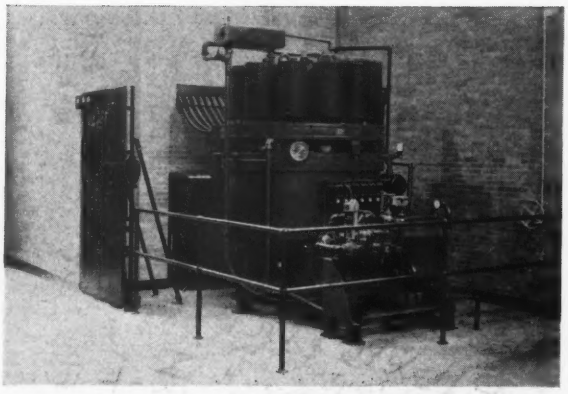


Fig. 5. 1000 kw., 250 v. grid controlled mercury arc rectifier with auxiliaries and control panels for steel mill service

Grid-control enables d.c. motors to be started at low voltage, and to be brought up to speed smoothly and gradually. Moreover, motors for drives where exact speed regulation is of importance may by this means be accurately and automatically controlled.

A factory-assembled grid-controlled rectifier with auxiliaries with a rating of 150 kw., at 250 v., is shown in the photograph at the head of this article. Such a rectifier set is therefore eminently suitable for just such applications as the above. It will be observed that the rectifier, the evacuating equipment, the vacuum gage, the ignition and excitation transformers, grid transformers, a.c. and d.c. circuit breakers, and all necessary controls are combined into one unit. The output voltage can be regulated from full value to zero, smoothly, by simply turning the hand wheel in the center of the control panel.

The main advantages of this type of speed control are its smoothness; its high efficiency at reduced speed, especially at the higher voltages; the simple control gear required; the very wide range of regulation obtainable, with stable operation even at very slow speeds; and the low maintenance cost compared with motor-generator sets used for speed control. Furthermore, several motors can be connected to different groups of anodes on a large multiple-anode rectifier, and each motor can be separately controlled. This type of control is particularly desirable for variable-speed drives of paper and textile machines, printing presses, conveyors, pumps, fans, blowers, compressors, mine hoists, rolling mills, and the like.

In addition to the above, the electrically energized grids may also be used to interrupt short circuits and other disturbances within less than one cycle. Moreover, they can be employed to reduce the voltage when service is restored after an interruption and gradually to bring the rectifier up to full voltage again. This feature is of great advantage in connection with many types of equipment which may be supplied with direct current by rectifiers.

Experience with a large number of other installations, both of the 250-v. and of the 600-v. classes, shows that mercury arc rectifiers possess marked advantages over rotating equipment, particularly where the apparatus has to operate for long periods of time at light loads, and without any attention. This is due to the high efficiency of this type of equipment at such loads, and to its ready adaptability to unattended operation. Moreover, no synchronizing is required, and neither a.c. nor d.c. system disturbances have any harmful effects on the rectifier, producing at the worst only momentary interruptions, especially when the grids are used for automatic clearing of faults, load limiting, and service restoration.

These advantages, combined with the low installed cost of a rectifier. Its immunity to dust and chemical fumes, and ability to withstand high momentary overloads and short circuits, make the mercury arc rectifier justly enjoy an ever-widening acceptance in many fields of application.

Piping Specifications

As a Result of the work of A. S. T. M. Committee A-1 on Steel, important recommendations were approved involving particularly the field of pipe and tubing materials. One noteworthy change was to issue revisions in the form of new tentative specifications* to replace immediately the standard A83-36 covering lap-welded and seamless steel and lap-welded iron boiler tubes. The new tentative specification A83-38T is especially significant because the committee has recognized the advantages of designating wall thicknesses by decimals in place of B.w.g. and fractions as well as the desirability of indicating permissible variations for wall thickness and weight in percentages rather than by the existing dual system. The former grade of medium carbon material in the specification was deleted and a new tentative specification A210-38T for medium carbon seamless steel boiler tubes was approved. The use of this material and the desirability of making certain modifications in requirements indicated the necessity of a separate specification.

Demands for recognized standardized requirements for carbon-molybdenum seamless steel boiler and superheater tubes resulted in new tentative specifications for this material. The close cooperation of consumers and makers resulted in a favorable consensus on the new specifications which bears the designation A209-38T.

For some time Committee A-1 has been developing standardized requirements for spiral welded pipe and there has now been issued a new specification A211-38T covering spiral welded steel or iron pipe 4 to 48 in. in diam. inclusive, with wall thickness from 1/16 to 11/64 in. manufactured by the following electric-fusion-welded processes: spiral lap-welded joint, spiral lock seam welded joint, or spiral butt welded joint. In order to cover spiral welded material greater than 3/16 in. in thickness, tentative revisions are being published in two existing specifications covering electric-fusion-welded steel pipe of sizes from 8 in. to 30 in. and sizes 30 in. and over.

*Printed copies of these new specifications will be available at the office of the American Society for Testing Materials, 260 S. Broad St., Philadelphia, Pa., by November 1. Each specification is printed as a separate pamphlet at 25 cents per copy or at reduced prices on quantity orders.

Power House Addition at Vineland

Municipal plant modernized and enlarged by installation of 400-lb. boiler and 4000-kw. turbine.

By R. A. CARLTON,
Chief Engineer
Vineland Municipal Electric Plant

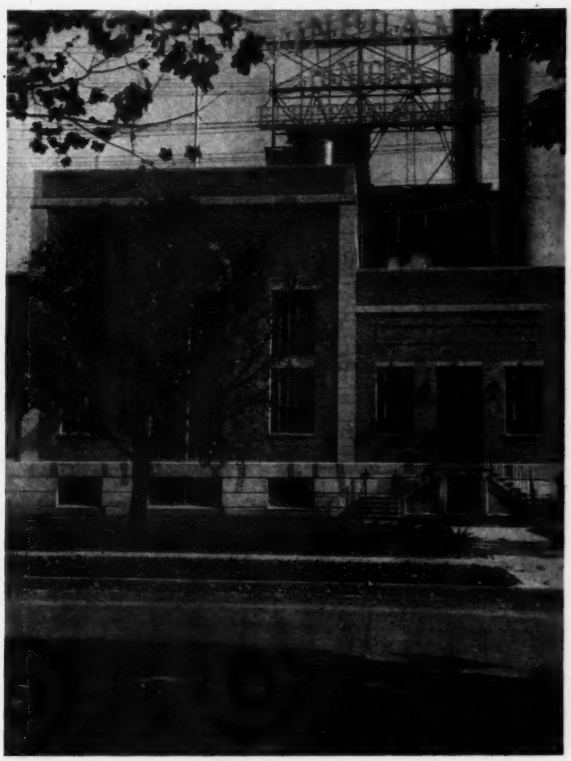


Fig. 1. New section of Vineland Municipal Plant

RECENTLY installed equipment in the Municipal Electric Plant in Vineland, New Jersey, has nearly doubled the electrical capacity of the plant, and has already demonstrated the better economy of modern equipment. The original plant consisted of two 250-hp., one 550-hp. and one 607-hp. boilers. These delivered steam at 200 lb. pressure to three turbine generators—a 3000-kw., a 1000-kw. and a 750-kw. unit respectively. The average evaporation with the old equipment ranged from 9 to 9.5 lb. of steam per lb. of coal.

Engineering work and supervision of the enlarged plant was done by the Scofield Engineering Co. of Philadelphia. All construction and installation work had to be done without interrupting the service of the existing plant. This demanded considerable ingenuity on the part of the construction engineers, as old equipment and building walls had to be torn down and new ones erected alongside the older machines while operating at full capacity.

One Boiler Replaces Two

The two 250-hp. boilers were replaced by a 4-drum, bent tube Stirling type boiler with 7900 sq. ft. of heating surface. This is a 790 hp. unit with a 400 per cent rating, capable of delivering 96,000 lb. of steam per hour at 400 lb. pressure and 750 deg. total temperature. It is fired by an hydraulic stoker with coal from a 900 t. overhead bunker. The outside coal handling equipment was unchanged, and the old steel stack is used to remove the combustion gases. After passing through a clinker grinder, the ashes are removed by truck.

Combustion is automatically regulated by steam pressure in the 400 lb. header, which controls the stoker feed and the forced and induced draft dampers. A complete record of boiler performance is recorded on instruments mounted in the boiler room. This board includes a 5-point draft indicator, a 2-pen re-

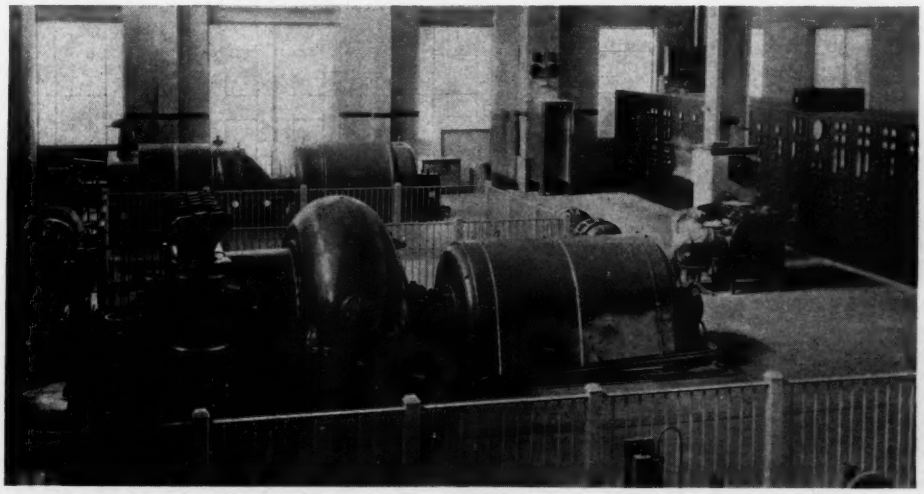


Fig. 2. Turbine room at Vineland. Old 3000-kw. unit in foreground, new 4000-kw. unit in background

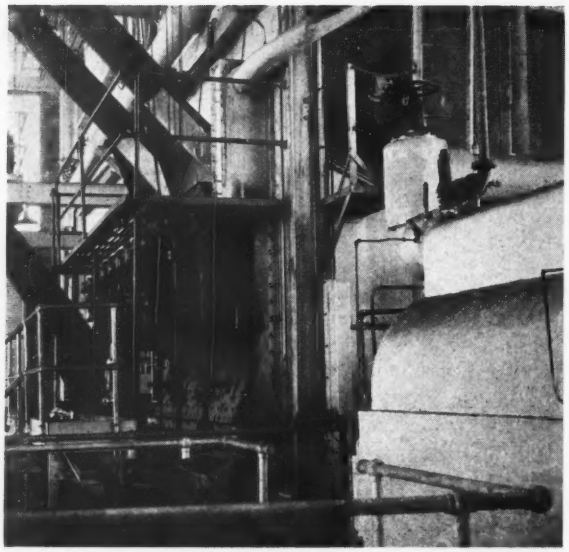


Fig. 3. Front of new boiler showing stokers with hydraulic drive

corder for steam pressure and temperature, a 2-pen totalizing recorder for air flow and steam flow, a water level recorder, steam and feedwater pressure indicators and a 4-pen temperature recorder for the preheater gas and air as they enter and leave the preheater.

Feedwater is supplied by two turbine-driven centrifugal pumps operating from either the 400 lb. or the 200 lb. steam lines. From the hotwell, feedwater passes through a low and high pressure deaerating feedwater heater, supplied with extracted steam at approximately 11 lb. and 50 lb. respectively, depending upon the turbine load. The low pressure heater raises the hotwell temperature from about 90 deg. to 190 deg. F. In the high pressure heater the water is raised to 300 deg.

Forced and induced draft fans are located above the boiler. Air from the preheater is delivered at 280 deg. Evaporation of the new boiler ranges from 10.75 to 11 lb. of steam per lb. of coal, which shows a decided improvement over the old equipment with its 9.5 maximum.

Steam for the old 1000-kw. and 750-kw. turbines is provided at 200 lb. from the old 550 and 607-hp. boilers, or, through a reducing valve and desuperheater, from the 400 lb. main. The old 3000-kw. turbine has been revamped to operate at 400 lb., thereby profiting by the better efficiency possible with the higher steam pressure.

The new 4000-kw. turbine has two points of extraction for feedwater heating. These extraction pressures vary from 11 to 44 lb. at the low pressure point, and 40 to 125 lb. at the high pressure point, as the turbine load varies from 1000 kw. to 5000 kw. The turbine exhausts at 29 in. of vacuum to a 2-pass surface condenser with 5000 sq. ft. of cooling area.

This turbine drives a 5000-kv-a., 60-cycle, 3-phase generator, delivering power at 2400 v. A new generator control board and distribution switchboard have been installed, giving a complete record of generator performance and power delivered. Remote controlled circuit breakers are housed in a new breaker room below the turbine floor. Power is transmitted from an outdoor substation at 6600 v.

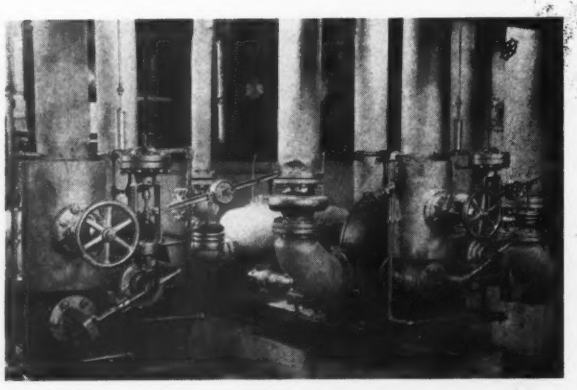


Fig. 4. Two new turbine driven boiler feed pumps

LIST OF NEW EQUIPMENT AT VINELAND

Boiler	Babcock & Wilcox Co.
Stoker	American Engineering Co.
Boiler Feed Pumps	Dayton-Dowd Co.
Feedwater Heater	Cochrane Corp.
Combustion Control	Bailey Meter Co.
Forced and Induced Draft Fans	Sturtevant Co.
Condenser	Foster Wheeler Corp.
Air Preheater	Prat-Daniel Corp.
Reducing Valve	Bailey Meter Co.
Desuperheaters	Elliot Co.
Turbine	Elliot Co.
Generator	Elliot Co.
Switchboard	General Electric Co.
Recording Instruments	Bailey Meter Co.

Provision has been made to facilitate future expansion, by means of replacing the low pressure turbines and boilers. The total cost of the new installation amounted to $750,000, of which 45 per cent was a PWA grant.

HARDNESS TEST: Alloy steels and cast irons are now being produced of hardness approaching so closely to that of the diamond that standard methods of measuring hardness are no longer sufficiently exact, according to J. S. Vanick of the development and research division, International Nickel Co., Inc. The rebound tests were found to require an average from 16 tests to narrow the variation to an acceptable point. The Brinell test by indentation with a tungsten carbide ball 10 mm. diam. under pressure of 3000 kg. for 30 sec. required only two or three determinations to get uniform values. This is the most satisfactory test to use, says Mr. Vanick, but improved testing devices and methods are needed to remove uncertainties in the results of hardness tests.

Heat, Temperature and Entropy

By A. BEMENT

TO BEGIN with it is essential to realize the distinction between heat and temperature. Temperature is the potential of heat, the strength of heat as it may be said.

Temperature is in no sense an indication of a quantity of heat. In the outdoor air in winter there is enough heat to melt iron, a large quantity of iron for that matter. But such heat is not available for the purpose because its potential is not sufficient. The terms heat and cold are commonly employed in a relative sense. The foundryman may complain that the iron in the ladle has become too cold for pouring into the mold, yet the metal may be at a red heat, so common expression has reference to some desirable process or purpose.

Heat flows or passes, only from a condition of higher to one of lower temperature. Like water, heat can not flow up hill. For example, in winter time, people add extra clothing when going out of doors as protection against the "cold", and the expression "penetrating cold" is often employed, suggesting that the colder condition has power of attack, that coldness has been acquired. This is not true, the discomfort experienced is due to loss of body heat to the lower surrounding temperature condition. Therefore, instead of acquiring cold, the person loses heat which causes the discomfort experienced.

With refrigeration the process is not one of supplying cold to the storage compartment, but is rather a process of abstracting heat from these compartments. The refrigerant at a relatively lower temperature acquires heat, and this loss of heat produces lowered temperature in the storage compartments. The action may be illustrated by the act of gathering up water with a sponge, the sponge is squeezed and the water expelled, then returned for an additional supply of water. So in refrigeration, the refrigerant goes out, gathers a quantity of heat, passes it to the compressor where its temperature is greatly elevated, then it passes to the condenser where heat is removed, then it goes back for an additional supply of heat. This heat that is removed from the storage spaces in spite of insulation is derived from the surrounding air which is at much higher temperature than the refrigerated spaces.

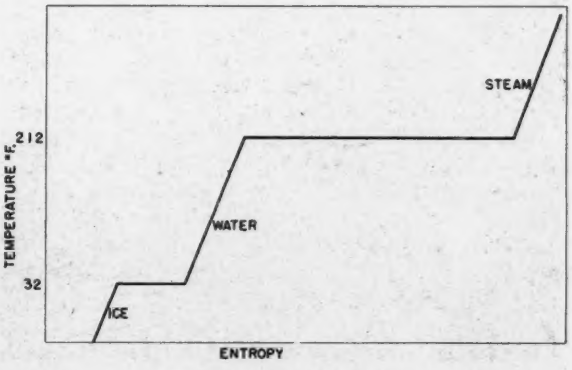
At the temperature of absolute zero, there can be no heat, or in other words, the condition of zero heat is at absolute zero of temperature. It therefore follows that any temperature above the absolute zero is a state of heat. That this is true is illustrated by the cake of ice that supplies heat to evaporated liquid oxygen. It therefore may be said that every temperature above the absolute zero is a relatively hot condition. For example, a temperature of 100 deg. below the Fahrenheit zero is hot as compared with one of 200 below.

Quantities of heat, i.e., heat units, that may be present in a substance depend on what the material is. Water has the highest heat capacity, for one degree F. rise its capacity per pound is one B.t.u. Air has about one quarter as much and other substances have various capacities all less than water. Thus if the specific heat and temperature of a substance be known together with its weight, the amount of heat may be calculated, provided no other influences intervene. Another factor, however, enters the problem in some cases. It is that of latent heat. It is not sufficient to know the temperature and weight of steam to determine its heat content because most of its heat is not shown by either temperature or weight, and this fact must be taken into consideration, which leads to the subject of entropy, about which so much mystery has prevailed.

In the standard temperature-entropy diagram, temperature is indicated by the vertical and entropy by the horizontal scale, with this recognized foundation, the effects of heat as applied to water is indicated on the accompanying diagram. Water in its lowest heat stage is solid in the form of ice. On the application of heat its temperature rises to 32 deg. F. at which point temperature, for the moment, ceases to rise, and with further application of heat, the ice is melted to water with an input of heat not indicated by rise in temperature until the ice has all been changed to water. Then the continuing application of heat raises the temperature of the water to 212 deg. F. at which point, temperature remains stationary for a long period. When the water has all been evaporated into steam, the continued application of heat further raises the temperature of the steam.

It is apparent that there are three periods, one with ice, one with water, one with steam in which the acquisition of heat results in rise in temperature, in other words accumulation of sensible heat. Likewise there are two periods of heat acquisition with no change in temperature during which much heat becomes latent.

Referring to the standard accepted heat-entropy diagram it is evident that all that can develop from the application of heat to water in its different conditions, leads to the conclusion that entropy increases directly as the sum of the sensible and latent heat, i.e., the total heat involved, and inversely as the total temperature. In other words entropy is the total heat divided by the total temperature. Not a very mysterious matter.



Temperature—Entropy Diagram

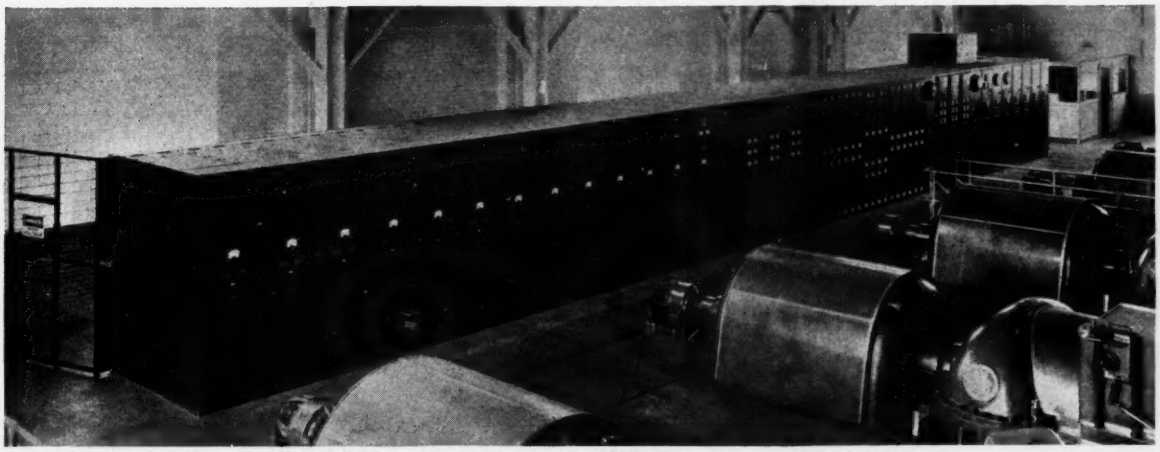
PICTURES

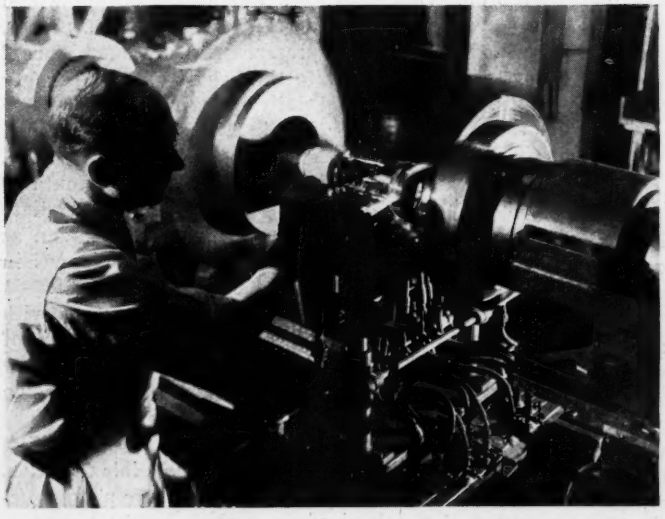
Heavy guns of modern industry are tuned to the demands of peace and the ever-increasing requirements of urban and rural districts for power. This symmetrical arrangement of three Maxim silencers and two air intakes at the new REA Diesel plant of the Thumb Electric Cooperative in Michigan is symbolical of the interdependence of government, capital and consumer, backed by the operator and management, in the present drive to extend electric power facilities to rural areas.

In our opinion the picture at the right could have been vastly improved if the photographer had rounded up a bevy of Hollywood bathing girls and draped them around this gear, but we had to accept it as it came to us. Perhaps it is just as well since it enables us to concentrate more on the gear itself. It is over 20 ft. in diameter and was made in two halves from steel castings weighing over 40,000 lb. It was made by Foote Bros. Gear and Machine Corp. and will transmit 1500 hp.

Like the shell of a gigantic snail, this 45,000 lb. cast iron pump casing makes an interesting photographic study in the Allis-Chalmers shops at night. It belongs to one of four 72-in. double suction sewage pumps now under construction at the Allis-Chalmers shops for the Racine Pumping Station of the Sanitary District of Chicago. Each complete motor driven unit will weigh 135,000 lb. and will be capable of pumping 375 cu. ft. per sec. of raw sewage against a 19.5 ft. head.

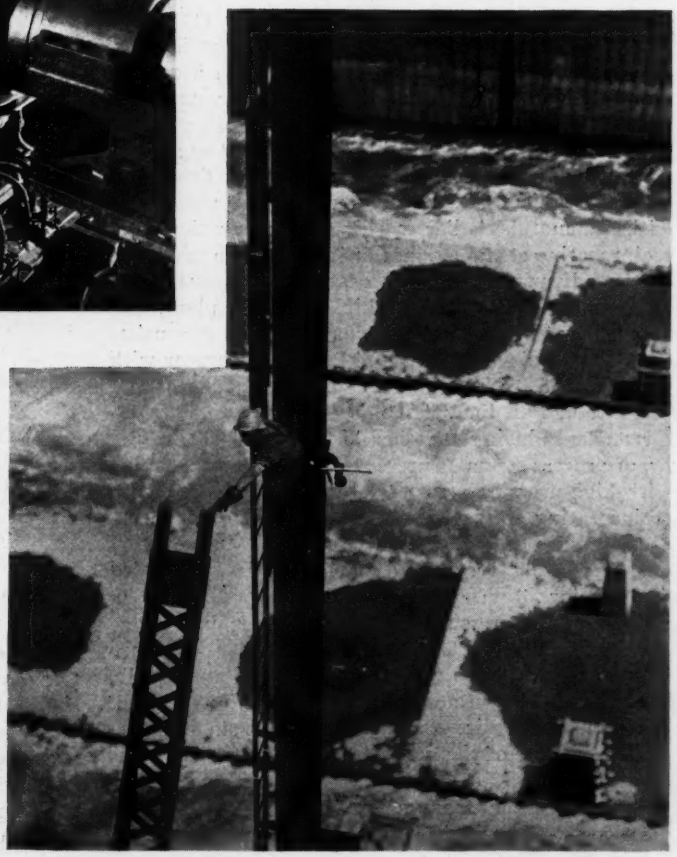
# of Engineering Interest





A personification of neatness is this General Electric metal clad switchgear installed in a large rayon plant on its generator-room floor. The equipment controls 3—2400 v. 2 phase 60 cycle and 3—3450 v. 3 phase 150 cycle generators and 20 feeders.

Machining Glass? Well not exactly, but something like it. Using a special lathe the operator above is putting the finishing touches to a large electron tube in the Bloomfield, N. J. plant of Westinghouse. He is sealing the cathode mount to a bulb assembly, using a wooden paddle to shape the glass which has been softened by gas torches.



"Ready!" In the view at the right another steel member is maneuvered into position on the concrete placing trestle high above the Columbia River at Grand Coulee Dam. Twelve thousand five hundred tons of steel will go into this great trestle which will be buried in the concrete as the dam rises to its 550 ft. height. (Photo. Bureau of Reclamation.)

How About the Small Industrial?

Advantages offered by high pressure are generally considered beyond the reach of the small plant that measures its load in hundreds of kilowatts. Yet the European firm of Emil Adolff has been operating a 1400 lb. once through boiler and 850 kw. engine generator sets since 1936 with a degree of success that warrants close study as to the practicability of small tops. This article is based on one written for the V.D.I. by C. Vest, chief engineer of the Emil Adolff bobbin and spool works, Reutlingen, and translated by Sulzer Bros. of Winterthur, Switzerland, manufacturers of the 40,000 lb. per hr., 1500 lb., 800 deg. F. Monotube boiler, 850 kw. engine generator sets and auxiliaries.

INDUSTRIAL STEAM POWER PLANTS, where the output is only a few thousand or even a few hundred kilowatts, have not heretofore considered it practical to make use of the advantages of high-pressure steam, since boilers with natural circulation are too expensive for such plants, and it was generally supposed that no tubular forced circulation boiler could be used with feedwater containing even a slight trace of oil. If the small high-pressure boiler plant is to be developed, it is essential that it should not be sensitive to traces of oil in the feed for low efficiencies of small steam turbines nullify the thermal advantages of high-pressure steam, and, although small reciprocating engines give good efficiency at full or partial loads, even if the admission pressure is high, they are liable to foul the condensate with a certain amount of oil unless special precautions are taken to avoid it.

Service results of the high-pressure steam plant installed, in Europe, at the works of the firm Emil Adolff, bobbin and spool manufacturers, show that with a monotube boiler working in conjunction with reciprocating steam engines, it is possible to make use of the advantages of high-pressure steam even in a small plant. A complete high-pressure plant, developed by Sulzer Brothers, was installed. It consists of: A monotube (once through) steam generator with an output of 44,000 lb. per hr. of steam at a working pressure of 1422 lb. and 788 deg. F.; two steam transformers, producing together 35,000 to 40,000 lb. per hr. of process steam at pressures of from 80 to 225 lb., with high-pressure steam to steam superheaters; two reciprocating single-cylinder steam engines, working at a pressure of 1350-1422 lb., each with an indicated output of 1200 hp. at 250 r.p.m. and direct coupled to a 850 kw., 3 ph. generator.

In the high-pressure engines steam expands in one stage, normally to 130 lb., although the back-pressure may be adjusted to any figure between 85 and 230 lb. as required. Because of the great fluctuations in back pressure, the designers chose a single-stage steam engine, in spite of the great drop in pressure that was required.

The monotube steam generator consists, in its simplest form, of a single length of tubing although in the present case there are two tubes in parallel. The generator being constructed without drums, the nests and coils of tubes can be arranged favorably with respect to the varying temperatures of the flue gases so it is possible to limit the use of special steels mainly to the superheater tubes and a few pieces which are subject to particularly high thermal stresses.

Ends of the tubes of each separate nest are led out at the side and connected outside the boiler to the next nest. This method of construction has the advantage that the temperatures of the water, steam and flue gases and consequently also the heat transmission in separate zones, can be supervised while the boiler is in operation and the result of this can, in as far as it is necessary, be made use of for the automatic regulation of the boiler.

Walls of the combustion chamber are cooled on all sides by tube coils reaching down to the grate. All tube connection within the boiler are made by oxy-acetylene welding, an inset ring being fitted at each joint. The type of firing adopted for the Monotube steam generator is a traveling-grate stoker with zone-regulated forced draft.

The three-throw high-pressure feed pump, driven by a 3 ph. brush shifting motor has an output which can be regulated between 9000 and 48,000 lb. per hr. at a maximum service pressure of 2100 lb. Figure 2 shows that in contrast to the usual types of plunger pumps, the suction and delivery valves are not fitted on the pump cylinder but in a separately arranged casing connected to the pump cylinder by a pipe. The pump is driven by a three-phase commutator motor with speed regulation to suit the intermediate steam temperature; this temperature being taken as an approximate scale for measuring the changes in the amount of heat supply.

Automatic control is by two thermostats with regulators for the boiler feed and for injection of water to regulate the steam temperature. These regulators are actuated by the thermostats, as shown by Fig. 4, and operated by oil under pressure. The two thermostats are fitted in the superheater tubing outside the boiler, in an easily accessible position. One of the thermostats is operated by the steam temperature at the beginning of the superheater; (for medium load about 644 deg. F.); the other by the temperature of the steam leaving the boiler (end temperature). When the load fluctuates quickly, it is not possible to keep the final steam temperature constant by means of the feed regulator alone. Consequently, for the fine regulation of the final temperature an injection regulator is also provided, controlled from the end thermostat.

Engines

High-pressure reciprocating steam engines were chosen because of: The working conditions prevailing; the small power output; the high steam conditions; and the fluctuating load. Their efficiency under such conditions is higher than that of steam turbines and they are less sensitive to fluctuations in back pressure. A longitudinal section through the engine is shown in Fig. 1. The method of attachment of the cylinder block, forged from open-hearth steel, shows many points of difference from methods hitherto

adopted. The block is not attached direct to the rigidly anchored frame of the engine, but is overhung and suspended on heavy steel beams. In this way the frame of the engine, and working parts subject to high mechanical stresses, are affected only to a slight extent by heat transmitted from the cylinder. The overhung arrangement of the cylinder block has the further advantage that it allows free expansion. As a surface for the piston, a liner of high-grade cast iron is pressed into the cylinder block. The forged steel piston is in several parts and has eight flexible cast-iron rings.

Stuffing boxes through which the piston rod passes are fitted with metallic packing. Immediately adjacent to each of the two stuffing boxes, the piston rod is supported by special water-cooled bearings, which relieve the stuffing boxes of lateral pressure from the rods. The slight cooling experienced by the surface of the piston rod as it passes through the water-cooled bearings favors the maintenance of a film of lubricating oil, thus contributing in a large degree to reducing wear in the stuffing boxes.

These engines are fitted with Sulzer valve gear as used in medium pressure engines: A spring-loaded shaft-governor, connected to a rotary-piston servomotor, operated by oil under pressure and arranged for remote control of speed and pressure. The spring-loaded governor, and consequently the valve lift and the cut-off, are controlled not only by the speed of the camshaft, but also by a rotary servomotor, under the influence of the boiler pressure, and fitted on the camshaft. The steam generator and engine are therefore positively coupled together. Should the speed suddenly increase above a predetermined limit, as when the load is suddenly removed, the valves of the engine are released and act as quick-acting automatic stop valves. The admission valves are of the single beat type, the valve spindle being guided in a special bushing.

An automatic valve, governed by the steam pressure and steam temperature, (k, l and m of Fig. 4), is for reasons of safety used before the engines. Should the boiler regulator fail to act and the pressure or the temperature become unduly high, this valve closes. This device ensures that the engines can be run only under normal conditions of pressure and temperature.

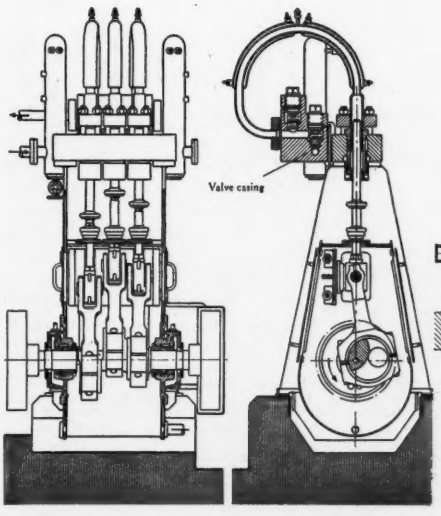
The highly loaded bearings of the crankshaft, crosshead and valve control gear are fitted with a system of forced lubrication. The returning oil is led through filters. The cylinder lubrication works independently of the central lubrication system. The cylinder oil is measured out, distributed and delivered by means of a high-pressure sight feed lubricator, driven from the camshaft. For lubrication, a pure non-compounded mineral oil with a viscosity of 8.3 deg. Engler at 100 deg. C. (212 deg. F) and a flash point of 350 deg. C. (662 deg. F.) is used. Oil consumption of the high pressure cylinder at full load amounts to only 200 to 250 grams[1] per hour or about 0.2 grams per b.hp. hr. This low oil consumption can be attributed partly to the suitable design of the cylinder and piston, and partly to the small diameter of the cylinder.

According to observations and measurements, the oil forced into the high-pressure cylinder is practically all expelled again in the exhaust. The oil content of the exhaust steam fluctuates with the load and amounts to between 0.009 and 0.018 grams per pound[1] of exhaust; the percentage being least at full load, since the engine is lubricated uniformly irrespective of the load. About 80 to 85 per cent of the oil introduced into the cylinders is recovered again by the baffleplate oil separator. In order to separate the oil still remaining in the steam, a special oil separating device is fitted in the condensate tank, and a coke filter in the feed line (not an activated coke filter). The oil content of the condensate fed into the high-pressure steam generator fluctuates between 0 and 3 milligrams per litre.[1]

Service Records

During the first weeks of service, engines caused some difficulties were encountered since the steam line to the engines leaked due to changes of temperature

[1]Approximately ½ to ⅝ of a pint per hr. On the basis of 8,000 drops and 400 grams per pint 1 gram (0.03527 oz.) would be equivalent to 20 drops. Thus the consumption would be 0.2 gr. or about 4 drops per b.hp. hr., the oil in the exhaust steam about 0.18 to 0.36 drops per pound and the maximum oil in the condensate 0.23 drops per gal. There are 1,000 milligrams in a gram, 1,000 grams in a liter of water and 3.785 liters in a gallon, so that this last value would be somewhat less than 1 part per million of oil in the condensate.



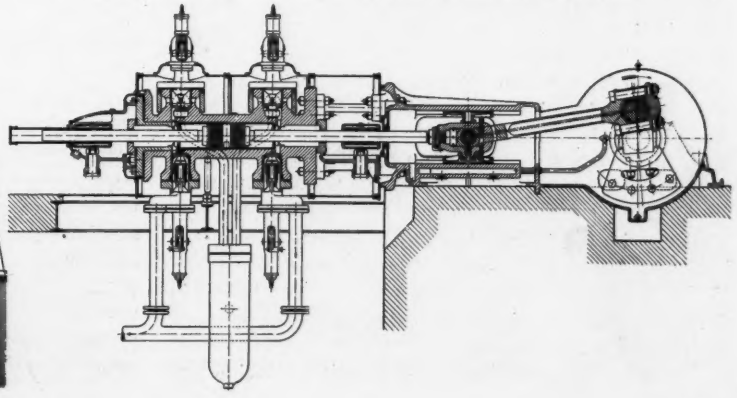


Fig. 1. (Below) and Fig. 2 (Left). Cross sections of the engine and feedpump

Each of one of the two high pressure engines, 9.84 in. bore and 23.62 in. stroke, drives a 850 kw. generator at 250 r.p.m. and develops 1250 i.h.p. Throttle conditions range from 1350 lb., 707 deg. F. to 1490 lb., 806 deg. F. and the back pressure from 85 to 940 lb. abs. The triplex boiler feed pump has a special valve arrangement which prevents the 300 to 400 deg. F. feedwater from coming in contact with the plunger and packing.

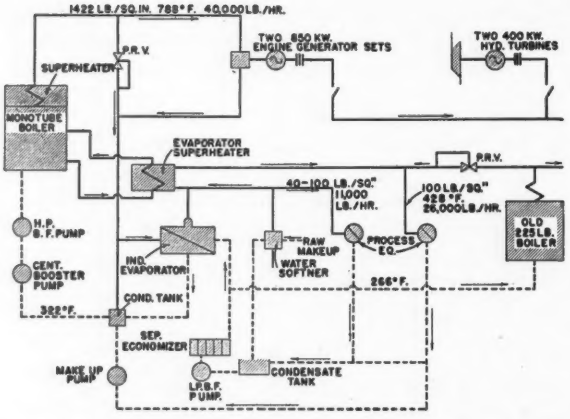


Fig. 3. Flow diagram showing how the high pressure turbine works in with the old to give flexibility

Process steam requirements at from 100 to 115 lb. normally range from 26,000 to 40,000 lb. per hr. in the day time and 13,000 to 22,000 lb. per hr. at night. Power requirements range from 1200 to 1600 kw. during the day and from 500 to 900 kw. at night. Hydraulic turbines are available to carry peak loads so that normally the high pressure boiler operates alone. The old 225 lb. boilers may be used, however, either in parallel with the evaporator as shown or to supply the older 225 lb. engine generator sets which operate condensing and are not shown on the diagram. The old separate economizers also serve as an evaporator feed heater. Oil in the engine exhaust steam is removed by a baffle plate oil separator followed by a coke filter in the feed lines. High pressure makeup about 1 per cent is taken from process drain, evaporator makeup, about 25 per cent, is treated by a lime-soda softener. Some of the evaporator vapor is superheated in a steam to steam superheater.

when starting and stopping. The same trouble was found with the admission valves. The trouble was cured by adopting welding instead of flanges and by changing the double-beat for a single-beat valve. Occasionally, when starting the engines, the spindles of the admission valves seized. This was corrected: First by lengthening the period of heating; and later by changing the shape of the valve spindles. No experience was available to show the most suitable types of pistons or stuffing boxes, so that several different types were used for experimental purposes. The pistons which proved best were those with cast-iron rings. After 16 and 19 mo. service respectively these rings show no sign of wear or leakage to speak of. In the case of the stuffing boxes, both types used have proved serviceable as one of them has already seen over 10,500 hr. in service without being inspected or showing signs of leakage.

The high-pressure plant was put into service in January, 1936, and has since then worked day and night, except on Sundays and holidays. Up to November 30, 1937, it had run for more than 13,600 hr., supplying the whole plant with power and heat. During all this time, the plant has completely fulfilled expectations with regard to reliability of service and to economy of operation. An extensive series of tests were made, by the Wurttemberg Boiler Inspectors Association in January 1937, after the boiler had been in service for about 7500 hr. The tests showed that the output and efficiency of the boiler and steam engines were most favorable. The overall thermal efficiency in regular service with a greatly fluctuating load was found to average 82.5 per cent during an 11 hr. trial run, taking into account the losses in the steam transformers, intermediate superheaters, piping and steam engines.

In order to investigate the condition inside the boiler tubes, after about 5000 working hr., bends were cut out from the superheater at two places where deposits were most likely to be found. In one place the sample was absolutely clean, while the sample from the second place showed but a slight film of oil 0.1 to 0.2 mm. thick, and considered of no importance. The boiler had worked without any coke filter until that time. After 13,600 working hr. the tube nests and coils showed no change. In the brick-setting, the only erosion noticed was on the fire arch. The traveling stoker proved to be in very satisfactory condition.

After the plant had been working about 10,000 hr. a tube in the superheater burst while the boiler was being started, due to the superheater being heated up too quickly while working with hand regulation. Within 24 hr. the damage was repaired and the boiler again in full service. The steam transformers and the economizer plant are cleaned internally twice a year. The necessity for cleaning the transformers is shown by the increased pressure drop between the primary and secondary circuits which was designed for a maximum of about 21.3 lb. Even when the low-pressure boilers which act as heat accumulators not connected to the plant, fluctuations of 30 to 40 per cent in the load could be taken up with the high-pressure plant within 3 to 4 minutes, without any appreciable fluctuations in temperature or pressure.

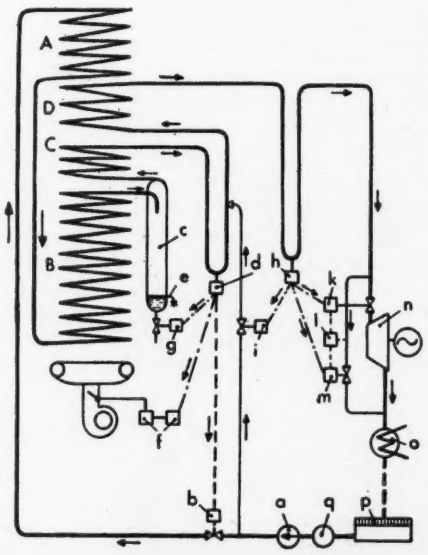


Fig. 4. Diagrammatic arrangement of the boiler and combustion control

The boiler is arranged in four sections: A, the economizer; B and C, the primary and secondary evaporating coils; and D, the superheater. The evaporator drains to the receiver p where it is picked up by the centrifugal booster q and delivered to the triplex feed pump a under positive pressure for delivery to the boiler. About 95 per cent of the feedwater is evaporated in the primary section B, preceding separator c in which the concentration is regulated by a continuous blowdown e. Drain g controlled by the intermediate thermostat d takes care momentarily of excessive feedwater. Control is automatic by oil operated servomotors actuated by the two thermostats d and h. Steam temperature at the entrance to the superheater is taken as an approximate measure of combustion requirements and thermostat d regulates the forced draft through f and thus indirectly through other equipment the fuel feed and induced draft. d also regulates the feed pump speed, the feed water flow through b and drain valve g. Final superheat temperature is controlled by thermostat h, which through i regulates a spray of boiler feed water injected at the superheater entrance. h also protects the engines n against excessive temperatures through valves k and m and in parallel with pressure regulator l.

Some phases of the economic problem involved in sulphur removal are discussed here to clarify possible confusion of statements in previous articles.

Removal of Sulphur from Flue Gases

By A. W. ANTHONY, Jr.
President, Pease, Anthony Equipment Co.

SOME of the problems of SO_2 removal from boiler flue gases by scrubbing were well outlined in Dr. Kleinschmidt's article in the June issue, and Dr. Johnstone's letter in the August issue has added much to the general information on the subject. Further clarification seems desirable on the important point of "net profit" to the operator.

The question is not one to be approached strictly from a manufacturing standpoint, because the principal and (hitherto the only) objective in flue gas cleaning has been the elimination of nuisances to the public. Smoke, cinders, fly ash, and SO_2 are such nuisances, differing in degree. Heavy smoke need not be produced, and it will not be considered. Cinders and fly ash, however, are tangible, and much has been done to prevent their discharge; in urban areas, at least, new or revamped boiler plants are usually equipped with solids-arresting apparatus, as a matter of course, without expectation of "net profit," solely to be "good neighbors." SO_2, not obvious to the eye, has been accepted as a necessary evil until rather recently, it being considered tolerable in most localities but not in others, depending on the sulfur content of the fuels and the character of the contiguous areas. If, however, both SO_2 and solids can be removed simultaneously in a single piece of apparatus, it would seem logical to consider doing the whole job of flue gas cleaning rather than the half job of merely removing solids; especially so if sale of by-product thereby becomes important.

Both authors mentioned recent practice in England, where virtually complete suppression of solids and noxious gas discharge has been required, and Dr. Johnstone touched upon some features of operation, practical as well as economic. He also mentioned studies in this country wherein recovery of sulfur values was the goal, and stated, "In no case has the final cost estimate been low enough to show a profit for producing sulfur in competition with natural brimstone." In setting up the cost aspects of such an operation, it is important that the objectives be clearly defined. Under the proposed conditions, there will be at least two:

1. Recovery of by-products, and
2. Elimination of objectionable nuisances.

From the viewpoint of accountancy, anything less than some equitable division of both capital charges and operating expenses, as between the two major objectives and possibly as between the several nuisances, would be indefensible.

Where flue gases are scrubbed well enough for satisfactory solids removal, absorption of sulfur compounds can be accomplished simultaneously. Then, in order to allocate fairly the costs of sulfur recovered, proportions of the fixed charges on the scrubbing apparatus should be charged to nuisance elimination, and a proportion to SO_2 recovery. The writer does not attempt to proportion these fixed charges, but calls attention to the importance of properly prorating them as sound procedure in arriving at true costs.

Decided advantages appear when it is proposed to eliminate SO_2 and solids simultaneously by scrubbing, which should markedly reduce both capital costs and operating expenses. For instance, scrubbers of the writer's design have been effective in removing solids from boiler flue gases since 1930. The acid character of the gases, however, required protective measures which increased the first cost and also the maintenance expense. As Dr. Kleinschmidt pointed out, these costs could be decreased by the recirculation of alkaline scrubbing solutions, because then the scrubber-shell, piping, settling, cones, etc., could be made from unprotected steel; in fact, maintenance of protective coatings (as at present) probably would be negligible, while an item of perhaps greater importance would be the increased availability of the boiler because of absence of the need to protect. The expectation of these benefits is logical, for in the ideal SO_2 recovery method an alkaline solution would be recirculated, into which the acid gases would be absorbed within the scrubber; the solids would be settled

out, the solution regenerated outside the scrubber, with the acid gases liberated under control, and the solution recycled with little loss. It will be seen, therefore, that the combination of a suitable scrubber with an alkaline SO_2 recovery method should be an important step towards solution of the whole problem of atmospheric pollution from flue gases. To the chemical problems involved, numerous investigators are seeking the answers.

With further reference to the economic side, studies made by the writer and associates indicate good possibilities for moderate profit or at least a "break even" basis, with the low sulfur coals burned on the Atlantic Seaboard, provided the fixed charges are apportioned rationally. It seems reasonable that the size and hence cost of the flue gas scrubber will vary with the rated quantity of coal burned, but that the size and cost of the SO_2 recovery apparatus will vary probably with the quantity of SO_2 recovered. Making some extrapolations which appear not unreasonable, the conclusion is reached that ultimately the annual cost of scrubbing equipment to do the "complete job," meanwhile producing by-product commercial SO_2, would be approximately the same as acid-proofed scrubbers removing solids only, without SO_2 recovery. The advantages may be summarized:

a—Credit for sale of SO_2.
b—Virtually complete elimination of need for maintenance of protection against corrosion.
c—Minimum boiler outage chargeable to maintenance of scrubbers.
d—Smaller induced draft fans and less power to drive them, because gases are handled at lower temperatures.
e—No erosion of induced draft fan wheels.
f—Improved "public relations," if the public is advised of the new methods being installed.

There are of course disadvantages:

a—The price for SO_2 is not fixed and definite, and it will fluctuate with supply and demand, but it probably will not depart far from the price of the contained sulfur.
b—Power plant men must know more chemistry.
c—There will be duplication, if solids eliminators are already installed.
d—Fears have been expressed regarding the "plume" or mist cloud which appears in cool weather at the tops of stacks discharging scrubbed gases. The writer knows of no instance of complaint because of "acid rain," real or fancied, from mist plumes of the original installation. If operating alkaline, neither would there be an alkaline rain.

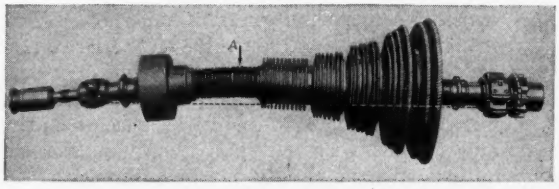
In summary, therefore, if public interest is justified in requiring the elimination of cinders and fly ash from power plant stacks, there is even more justification for requiring the elimination of SO_2, because probably the complete job can be done ultimately at little or no net cost over and above the cost of effective solids removal. If, however, SO_2 recovery is expected to show a profit after both paying its own way and meeting the entire cost on the admittedly expensive elimination of the fly ash nuisance, then the outlook for general acceptance is not favorable.

For a Bad Bend

STRAIGHTENING of a turbine spindle is by no means a rare job, but it is one demanding care and experience. The method is illustrated by the case of a 750-kw. reaction turbine, which crippled by a bent spindle, was quickly returned to dependable operation as soon as deflection in the spindle had been overcome by applications of heat.

The affected turbine, needed suddenly after several years of idleness, was warmed up by steam with the rotor not turning. Consequently the spindle was heated unevenly, a temporary bow developed, and, when sufficient steam to turn the rotor was finally admitted, the spindle ran eccentrically. Distortion, at first slight, was increased by friction until at half speed, vibration became severe. Inspection showed that some of the blading had been stripped and a permanent set had developed in the spindle.

As first steps in repair, the damaged blading was removed and the spindle replaced in its bearings, the point of maximum deflection being determined by slowly revolving the spindle and applying a dial indicator. Deflection was 15½ mils.



This illustration, with the spindle distortion greatly exaggerated, shows where the heat was applied at A by means of oxy-acetylene torches

The high side of the spindle was turned to the top, a dial indicator fastened to the turbine casing so as to register readings at the low side of the spindle, and the indicator set at zero. As shown in the accompanying illustration, heat was then applied at A on the high side of the spindle by means of two oxy-acetylene blowpipes. An asbestos ring was placed around the point that was to be heated, so that a quick heat could be obtained at that location.

As soon as heat was applied at the top, that side of the spindle began to expand and to rise so that the bow in the spindle was even greater than before the heat was applied. The spindle was then allowed to cool and the amount of correction, as shown on the indicator, was noted. The correction was made in a series of small steps, sixteen cycles of alternate heating and cooling being required to complete the operation.

For the various heats, the flames were applied for periods ranging from 20 to 90 sec. with a reduction in the bow of the spindle of from 2 to 6 mils for each heat. After the final heat, the maximum eccentricity was only ¾ mil and all points along the spindle were true to within less than ½ mil. When the new blading had been installed, the unit was reassembled and placed in successful operation. Since then, no further vibration has occurred.

Readers' Conference

These pages are open to readers for the presentation or discussion of any timely power plant topic. The Editors invite your participation.

Safety Valves and Second Hand Boilers

SAFETY Valve discharge requirements for oil or gas fired boilers have been considerably increased by the latest A. S. M. E. Rules. The necessary discharge capacity in pounds per hour is based on the heating surface of the boiler, but the allowable discharge capacity for a given size of opening, to which the safety valves are attached, is based on the allowable working pressure of the boiler, the higher the pressure the more the relieving capacity for a given size opening. Although some safety valves are guaranteed for an unusually high relieving capacity the allowable capacity is nevertheless limited by Table P-16 A. S. M. E. Code for Power Boilers, 1937 Edition.

It will be found that some boilers which were manufactured under previous rules will have insufficient openings to accommodate the necessary safety valve connections. As long as such boilers remain in their present setting the new rules do not usually apply unless the burners will obviously generate more steam than the safety valves will discharge. However, in most cases, where both ownerships and locations of boilers change, i.e., second hand installations, the rules for fittings and appliances for new installations must apply. Furthermore, second hand boilers are often penalized as to allowable working pressure, and this further reduces the allowable discharge capacity for the safety valve outlet.

From this it can be seen that those buying and/or selling second-hand boilers, should familiarize themselves with regulations pertaining to their particular locality or solicit the advice of a municipal, state, or insurance inspector and determine if boilers will require additional openings. If boilers are purchased from the yard of a second-hand dealer it is, of course, less expensive to provide the necessary openings while the boilers are still at the shop rather than after installation.

An additional safety valve may also be installed on the main steam line, but the size permitted is limited to one-third the cross-sectional area of the main to which it is connected. It is obviously desirable to limit the capacity of a safety valve installed on the steam main. If the capacity of such a valve is large, at each popping of the valve, water may be drawn into the main, possibly injuring machines or affecting process. Where additional openings are required it is best to provide such openings as will permit compliance with the more desirable rule, namely that safety valves should be "connected to the boiler independent of any other steam connection."

These openings, when exceeding the diameters shown in Fig. P-40, A. S. M. E. Code, should be reinforced in accordance with Par. P-268 of the Code, whereof the advice of the inspector or a reputable boiler maker should be solicited. There are some reinforcing nozzles manufactured which are guaranteed to meet the requirements of the paragraph referred too. If these are installed according to directions on the size of opening for which they are designed they will not weaken the boiler shell or drum and will consequently meet with the approval of the inspector.

Dallas, Texas. C. F. MAY.

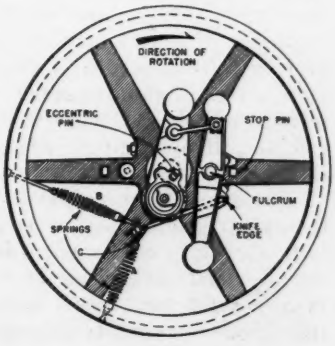
Steam Engine Governors

IN THE READER'S CONFERENCE of June issue there appeared a question from the Massachusetts License Examination answered by Zenas Allen. The question is:

"You have two American Ball angle compound engines, driving direct current generating units. When connected in parallel and without load, each engine runs at 300 r.p.m. When the load is thrown on, one engine speeds up to 306 r.p.m. and the other slows down to 294 r.p.m. What is wrong and how would you remedy the trouble?"

He gives as his opinion that the engine which picks up speed under load has a defective governor. I do not believe that this is the cause, as it is quite possible to have an inertia centrifugal governor in perfect mechanical condition increase its speed when the load comes on. The difference in the characteristics of the two engines is most likely due to the adjustment of the governors.

An inertia centrifugal governor can be made to run faster under full load than under no load, because its action is entirely different from a purely centrifugal governor in which there is a very definite position of the governing mechanism for each engine



Arrangement of the governor as used on the American-Ball engine. Two springs are used to counteract the effect of centrifugal force. Tightening spring B and slacking spring A makes the governor more sensitive. Tightening both at once, as can be done by nut C increases the speed

speed. In a perfect inertia governor the governing unit would move through its entire range while the r.p.m. would remain constant.

In practice it is not possible to build a governor which is frictionless with all forces acting upon it in perfect balance through its entire range. This results in a slight fluctuation in the speed, which can be controlled to increase or decrease as the load comes on. If it is desired to have the engine speed up under load it can be done by increasing the force which tends to speed up the engine, or, weaken the force which tends to slow down the engine as the governor moves to the full load position. As the spring of the governor tends to lengthen the cutoff and the centrifugal force of the weight in the inertia bar tends to shorten the cutoff, this law may be stated: "If the weight in the inertia bar and the tension of the spring are so adjusted that the centrifugal force increases faster than the tension of the spring, the engine will speed up under load."

In the problem with a governor as illustrated, the remedy for the different characteristics, if it were decided to have both engines operate at reduced speed when under full load, would be: Lighten weight in the inertia bar and reset springs for proper speed in the engine running 306 r.p.m. at full load. The difference in speed at various loads can be held to two or three r.p.m by changing the relative tension of the two springs. Within limits, slacking radial spring A and tightening spring B reduces the drop in speed under load. The weight to be removed would be a matter of experiment, making only small changes at a time.

The engine running 294 r.p.m. could be synchronized at different loads by the adjusting springs as stated above.

To make both engines increase speed under load it would be necessary to add weight to the engine running slow and synchronize by adjusting the springs of both engines.

Philadelphia, Pa. ALBERT NOLLER.

Licensed Operating Engineers

IN RESPONSE to E. Dablemont's article on the value of licensing operating engineers, I must state that he is quite mistaken in referring to a license as a mere scrap of paper. After all it is a certificate of qualification and it indicates that a person is qualified to operate power plants.

It is my belief that all power engineers should be licensed by the Federal government as are marine engineers. The examination should be based on engineering principles such as chemistry, physics, mathematics, etc., in an elementary way such as is covered in high schools. I always wonder how a person can call himself an engineer when he is ignorant of all engineering principles.

The examination could be divided into a written theory part and a practical part which would be given in a laboratory on standard power plant equipment.

All examinations can cover the power plant field in a general way. It is unreasonable to have an examination cover a certain specific make or type of apparatus, and it is practically impossible for a person to have operating experience on all the different makes of equipment. Therefore the examiner can ask only general power plant questions which to some people seem to be disconnected and unrelated. Although I can't see it that way, because all the questions deal with power plant equipment and the questions must cover as much of the power plant as possible.

Because many states do not require licensed operating engineers and others have weak license laws many operators of power plants look at licenses with contempt, not realizing that a strong uniform license law can only benefit them by keeping out unqualified men.

South Vineland, N. J. TARQUIN DE ROSA.

Common Operating Faults

MANY OPERATING engineers have quite erroneous ideas which cause them to be inefficient in their work and tend to make operating and maintenance costs higher. Let us take some examples.

It is quite unnecessary to have pump glands dripping water which comes either from the lantern seal or direct from the casing. Even though the maker provides a drain opening in the gland wells, this is not a direct indication that the glands must drip. Provided the pump holds a good suction, delivers well and runs with fairly cool glands, it is quite all right if the amount of drip water along the shaft is nil.

Some time ago the writer repacked a large circulating pump, ran it for a day and then, as it was all right, shut it down until needed. A few weeks later he found the glands literally spouting water. He nipped up on them, but for several days he came in to find the same condition. Then, one day, he happened to be on the spot when this pump was started up by the engineer. This man got it running, inspected the oil rings and then got a wrench and loosened the gland nuts until the water started to flow. All this happened within a minute of starting. Asked why he did this he replied, "To keep the glands from getting hot." No explanation could convince him of his error, but, fortunately, the writer was in a position to give him direct orders to leave the glands alone. He did this, but it was greatly against the grain.

Another common error is the practice of throttling gate valves. Throttling should never be allowed with this type of valve and the error is aggravated when superheated steam is the medium. The whole idea and design of gate valves is to give a full, unrestricted flow and, if the service requires throttling, another type of valve should be used. Once the faces of gate valves become scored through wiredrawing it is not by any means a simple matter to repair them.

When dealing with brushes and brush holders of electric motors it is desirable to put the holder as close to the commutator as possible to allow getting the full length of service from the brushes. When, as is often seen, the holder is set some distance away, the brushes have to be discarded when they are still quite long and this replacement cost, when multiplied, adds up to a considerable amount.

Another case of sheer, careless operation was wit-

nessed recently. It was found that the zeolite tanks were not giving good service. After regeneration they were not delivering anything near the number of gallons before requiring another regeneration. The brine solution was up to strength and the beds were good. The solution was simple but reflected little credit upon the intelligence of the men concerned. Each shift had got into the habit of backwashing the zeolites directly after coming on duty. Even though the zeolite had been put in service barely an hour before, it got backwashed nevertheless. Naturally, this was not allowing the bed to get settled and water got through before the calcium and magnesium could be eliminated. When orders were given that backwashing should be done only after the zeolites had shown signs of hardness all the trouble disappeared. Just a little thought on the part of the operators and a little more supervision would have eliminated any trouble at all.

One other instance comes to mind. The boilers were of the water tube type, three wet drums, a dry drum and a superheater drum. The gage glasses were of the flat type with mica sheets facing the glasses on the water side. The cost of renewal is quite an item and the mica has a tendency to get cloudy, which renders the level difficult to see after a time and the glass has to be taken down and opened up for cleaning. The steam temperature was 450 deg. F. wet and 600 deg. F. when superheated. It was suggested to the engineers that an ordinary round glass would serve the purpose just as well as the flat type and save money, as they are quite satisfactory up to 500 lb. pressure and 500 deg. F. The engineers replied that, as their temperature was 600 deg. F., this type of glass would not hold. Up to the time of writing it has been quite impossible to convince them that, as the gage connections are from the wet drum where the temperature is 450 deg. F., this objection is quite invalid. All they can see is that the chart shows 600 deg. F., so they continue to give themselves work and cause their costs to rise by using the other type of glass.

Passaic, N. J. MARK BELL.

Carryover Indicator

BOILER WATER carryover is always objectionable, its results, the cause and prevention are well known, and since its presence is not always apparent to the operator until trouble has developed, some advance indication is desirable. To accomplish this result, a handy and easily made indicator was installed in one plant where boiler water conditions must be closely watched to preclude any chances of carryover. With some variations it should make an indispensible instrument in every plant where carryover possibilities exist.

Figure 1 shows how this indicator was made up. A continuous sample of steam is taken from the boiler lead through a fixed orifice and discharges into an expansion chamber and cooling coil. The condensate flows through copper tubing to the "indicator" which is located on the boiler front in such a position that it is visible to the operator at all times. Figure 2 shows the "indicator", which is a plain cylinder about 2 in. in diameter and 10 in. high, in the bottom of which

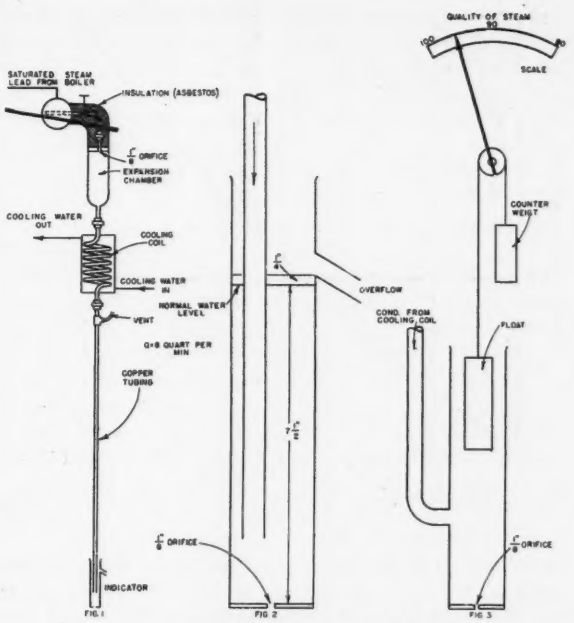


Fig. 1. Carryover indicator
Fig. 2. Detail of indicating element
Fig. 3. Indicating element finally adopted

is a fixed orifice which allows a continuous discharge of condensate. When the flow of condensate increases due to moisture in the steam, the excess will overflow through the opening or spout on the side, thus drawing the operator's attention and he can take the necessary corrective steps.

In order to determine the dimensions of the indicator and the location of the overflow spout, the condensate was measured, and with 150 lb. boiler pressure and using a ⅛-in. orifice it amounted to approximately 0.8 qt. per min. A few experiments with some tin cans having various sizes of discharge orifices showed that with a ⅛-in. orifice in the bottom of the indicator and with a discharge of 0.8 qt. per min. the water level would stand at 7.5 in. The overflow was then located ¼-in. above the normal water level.

Since this device indicates only the presence of moisture above a certain fixed amount and it was desired to have some quantitative measurement of the steam quality, the relation between moisture content in the steam and the height of water in the indicator was investigated.

The flow of steam through an orifice is in accordance with Napier's formula when

$$Q = \frac{A \times p}{70 \sqrt{a}},$$

where a is the quality of the steam, the flow will vary as

$$\frac{1}{\sqrt{a}},$$

with constant steam pressure. The values of Q for various values of a were tabulated. The flow of water through an orifice follows the formula $Q = 0.61$

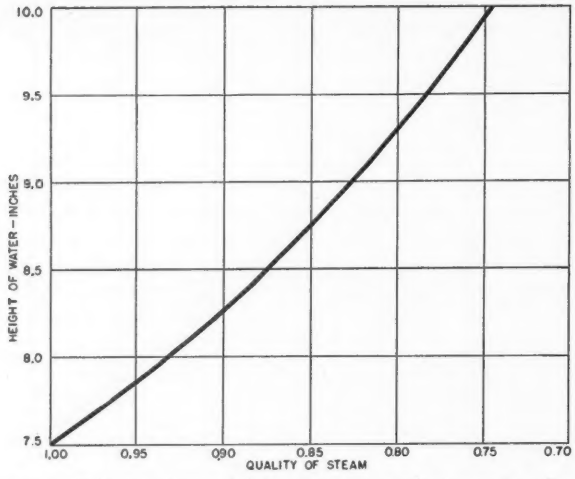


Fig. 4. Relation between height of water in indicator and quality of steam

A $\sqrt{2gh}$, or Q varies as $\sqrt{h}$. Values of h for various values of Q were then tabulated.

With the above information the curve, Fig. 4, was drawn, showing the relation between height of water in indicator to quality of steam.

The indicator shown in Fig. 3 was then substituted for the original one. In this indicator a float actuates a pointer which indicates on a suitably divided scale the quality of the steam. With very little extra expense, light or bell alarms and a continuous recorder could be incorporated in this indicator.

Stainless steel or other material highly resistant to erosion, should be used to make the orifice plate in the steam line, and the expansion chamber, coil and indicator should be made of non-ferrous metal. The orifice in the steam line should be renewed when flow indications denote wear. The accuracy of this indicator can always be checked by titrating a sample of condensate and comparing this with a sample of boiler water.

Since the flow of condensate is directly proportional to the steam pressure, it is apparent that this indicator can only be used where the pressure is held constant.

Rochester, N. Y. JULIUS BRODSKY.

Boiler Develops Static Electricity

SOME PEOPLE may not be aware that a boiler is capable under conditions of putting out static electricity.

A fireman I once had learned accidently that when he hung his poker up over the edge of the setting and the safety valve would pop off against the end of the poker it would heavily charge the poker with static electricity. Being something of a wag, he would wait till some loafer was standing around and just after the boiler would pop he would ask him to kindly hand him the poker. It would almost knock the man down who touched it. Of course this static will not "stay put". After it is generated it will escape in a few minutes. Now note the following:

I was operating an electric light plant in an Ohio city located on the C. H. & D. Ry. One night I was called out of bed at 1 a.m. by the conductor of a local freight that had just pulled in saying that his fireman had just been knocked down on the tender of the engine by getting up to and touching the spout of the water tank where they were taking water, and we having the only plant in town furnishing electricity it must be coming from our mains. I got our lineman out of bed and sent him to investigate and he returned saying we had no mains within a square of the tank and moreover there were no other wires anywhere near the tank.

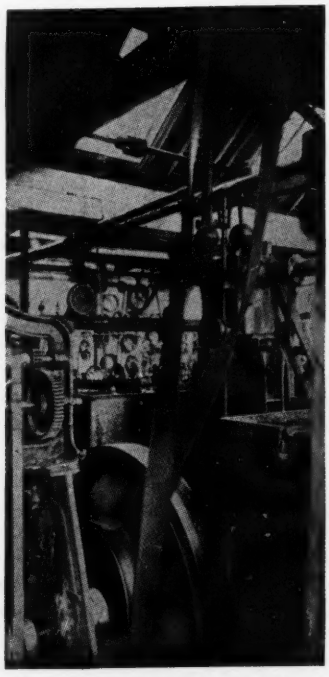
The next morning the engineer of the train stopped into our office to make complaint. I asked him if at first he did not stop a little short of the correct position to take water and the safety valves popped violently against the spout. Then he backed up to take the slack of the train and pulled up a little farther to get the tender under the spout and then the fireman got up and touched the spout and was knocked down onto the coal pile. In other words they had themselves made the electricity that gave the fireman such a scare. It was a very cold night, below zero weather, when it happened and the conditions were thus favorable to the storage of static.

Logansport, Ind. C. C. CUSTER

An Unusual Belt Drive

AS EVERY engineer knows, vertical belt drives are usually more troublesome than are horizontal drives, especially when the belt becomes loose. Yet in this photograph taken in a plant in England is shown a belt that was made loose purposely to give it the greater arc of contact which is plainly shown.

But that isn't all. In addition this belt is crossed in an unusual way, the claim being made that at the point of crossing the sides facing each other do not



Vertical, crossed and slack belt drive

grind. In other words, the faces do not rub against each other destructively as sometimes occurs in ordinary crossed drives whether vertical or horizontal.

All of these things are possible here because of the ideal pliability and sliplessness of the belt. Obviously, if the belt should slip the conditions as shown could not be maintained. Close examination of the photograph shows that the picture was taken while the flywheel and belt were in motion, the spokes being invisible, the belt being slightly blurred, and the pulling side of the belt is straight and therefore loaded.

The belt is 6½ in. wide and is made of leather. The driver pulley is 2 ft. 11 in. in diameter, runs 60 r.p.m., and the driven pulley is 2 ft. 3 in. in diameter. The distance between shaft centers is 12 ft. 1 in. The slack side of the belt operates with a slackness of 16 in. As will be noted, this drive is not perfectly vertical, but is nearly so.

Newark, N. J. W. F. SCHAPHORST.

Opposed to Waste, But—

THE CONTRIBUTION of W. F. Schaphorst in your October issue, describes a very interesting hook-up for the utilization of exhaust steam, which I am sure, could often be used to advantage, but it is in his concluding remarks that I find myself particularly interested.

Like Mr. Schaphorst, I am instinctively averse to waste in any form, though I am sometimes hard put to it to justify my attitude. I suppose that there is some kind of a religious element in it. The wholesale slaughter of little pigs, and the deliberate destruction of growing crops, for no other purpose than that of curtailing supply, strikes me as having something morally wrong about it, though I do not for a moment suppose that it will have any deleterious effect upon posterity, neither do I suppose that future generations will greatly suffer through the depletion of our fuel supply, indeed, I think that it is entirely possible that they may derive great practical benefit from it. Waste may not be the crime that we generally assume it to be.

Nature herself seems to offer a striking example of prodigious destruction and waste, though of course, the egocentricity of our viewpoint may invalidate our conclusions, perhaps the universe was not created for the benefit of man alone, I feel quite sure that my dog is convinced that it was created for his benefit, but then of course, we may both be mistaken.

As a matter of fact, we exist in a limitless ocean of energy, but so far, we have only discovered means by which we may avail ourselves of a very minute fraction of it, and in practice, we are deprived of the use of all but a small part of that fraction by the restrictions of a more or less, artificially created economic necessity.

All our engineering problems, and all our industrial ventures, appear to be conditioned by the necessity of finding a satisfactory answer to the question "Will it pay?" not in terms of human welfare, but in dollars and cents.

As a matter of fact, the production of heat and power through the agency of fuel, is very primitive and has many inherent disadvantages. The mining of coal, while affording a livelihood to many people, is not conducive to a standard of existence which our modern scientific advances might reasonably be expected to place within the reach of all. Its handling and transportation over long distances are cumbersome and expensive processes, and when we get the fuel to the boiler house, we create destructive temperatures of two thousand degrees or more in order to generate steam at often less than one-fifth of that temperature, and in doing this, we fill the atmosphere with dust and gas and make a hideous mess around the place generally.

Cannot our scientific attainments provide something better than this? Yes, of course they can, only in most cases they cannot provide a satisfactory answer to the question, "Will it pay?"

The experiment at Passamaquoddy was perfectly good engineering, but astonishingly bad economics, that is, when judged by current economic standards. Experiments have been made in connection with the production of power by means of the temperature differences existing at different depths in the ocean, which indicate the possibilty though not the economy of it. In the direct rays of the sun there are limitless sources of energy, to say nothing of our water falls and the power of the wind, as well as numberless other potential sources both known and unknown.

Unless we halt in the onward march of our scientific knowledge, when the necessity arises, we shall avail ourselves of many of these sources of energy, so we need not waste our time in fearful contemplation of the disasters which will overtake the human race when the supply of fuel gives out.

Man has always advanced through the irresistible urge of necessity, and may reasonably expect that long before our welfare is jeopardized by the scarcity of fuel, a beneficent necessity will have forced us into a situation where we may dwell contentedly in a purer atmosphere, under a brighter sky, where the clinkers cease from troubling and the ashes fly no more.

Bloomfield, N. J. JAMES O. G. GIBBONS.

Furnace Explosions

I READ with interest S. H. Coleman's article on furnace explosions. To my knowledge many of these explosions have been due to furnaces having stood for long periods with the dampers closed or almost closed. With the usual form of vertical slide damper, this leaves a space between the roof of the flue and the top of the damper which is unventilated even if the damper is not completely closed. This leaves a space in which combustible gases can collect. To prevent this a hole should be drilled in the damper top about one inch in diameter so that it becomes uncovered when the damper is nearly closed. This will permit some of the gases to escape which would otherwise be confined. To wholly prevent this trouble it is necessary to use swivel dampers which open sideways and equally for the whole height and therefore prevent this dead space. With the usual vertical slide damper there is always a dead space except when fully open, but this only becomes serious after long standby periods.

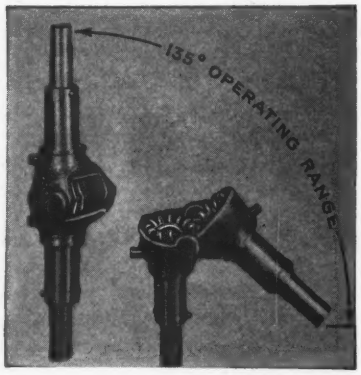
London, England. W. E. WARNER.

New Equipment

Information that you desire about any equipment will be gladly furnished without obligation. WRITE POWER PLANT ENGINEERING.

Bevel Gear

THE NEW UNIVERSAL bevel gear, made by the Condenser Service and Engineering Co., Inc., Hoboken, N. J., may be used at any angle over a range of 135 deg. and operates at an efficiency of approximately 95 per cent. The guard and



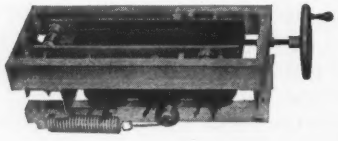
housing are made of cast steel and the gears of solid steel. Assembly is quick and simple, necessitating no lining up of shafting as it definitely accommodates itself to any position within the angle of transmission. Gears mesh accurately with no adjustment between 45 and 180 deg.

Continuous Voltage Control for Polyphase AC Power

ILLUSTRATED is a continuously variable polyphase reactor which develops a drop of 300 v. at 50 amp. per coil.

This device should be generally useful in industry when it is necessary to have a smooth, continuous control of polyphase power.

Standard parts are available for a number of sizes and the manufacturer will be pleased to extend engineering and production facilities in applying this reactor to electrical machinery, furnaces, and testing equipment.



By a careful study of mechanical resonance and the use of biasing springs, vibration has been reduced so that there is no objectionable noise.

A number of the units shown have been used for the past six years to vary the anode potential when exhausting large rectifier tubes having outputs up to 300 amperes.

Raytheon Reactors are custom built to meet given voltage and power requirements and more information may be obtained by writing Raytheon Mfg. Co., 168 Willow St., Waltham, Mass., stating the supply line voltage, frequency and number of phases, also the amount of power to be handled and the voltage control range.

Boiler Analyzer

THIS boiler analyzer made by the Crew Engineering Equipment Co., Inc., 101 Park Ave., New York, N. Y., utilizes nitrogen gas for indication of stack temperatures. The breeching bulb is of ample length, 17.5 in., to give accurate and average readings through the breeching. The model B analyzer, which is illustrated, is to be used in oil fired or natural draft coal fired boilers. In stokers and forced draft firing the model A analyzer is used.

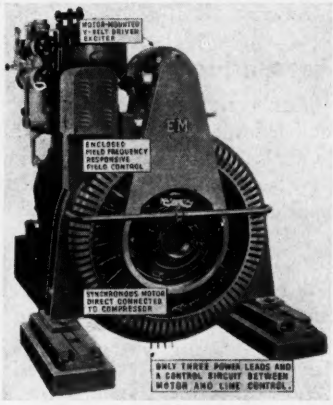
The model B analyzer indicates fan pressure, or rather air pressure below the grate, furnace draft, which should be taken above the fuel bed and flue gas temperature. These three indications may be assumed to give a complete analysis of the efficiency with which a stoker fired boiler is operating.

The model A analyzer is furnished with two draft gages and flue gas temperature indicator. In use, one draft gage should be connected at the last pass and one connected at the furnace, and the temperature bulb should be installed at the uptake. In this manner, an operator may instantly know the draft loss of the boiler.

In using the analyzer the boiler operator secures efficiency by working from flue gas temperature. Ideal temperatures for any pressure are, of course, known and when temperature of gases leaving the boiler are not correct, the other dials on the analyzer will instantly show why they are not correct. By adjusting controlling mechanism to a point to give proper furnace draft and proper draft loss and proper air pressure, the temperature of gases can be brought to a point of maximum efficiency. When this is done, high CO_2 may be assumed.

"Packaged" Motor Drive

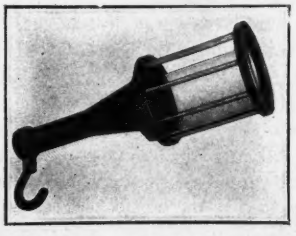
A DEVELOPMENT which simplifies wiring and installation, and reduces floor space required for direct-connected synchronous motor drives for larger reciprocating compressors such as used for refrigeration in air conditioning, is announced by Electric Machinery Mfg. Co., Minneapolis, Minn.



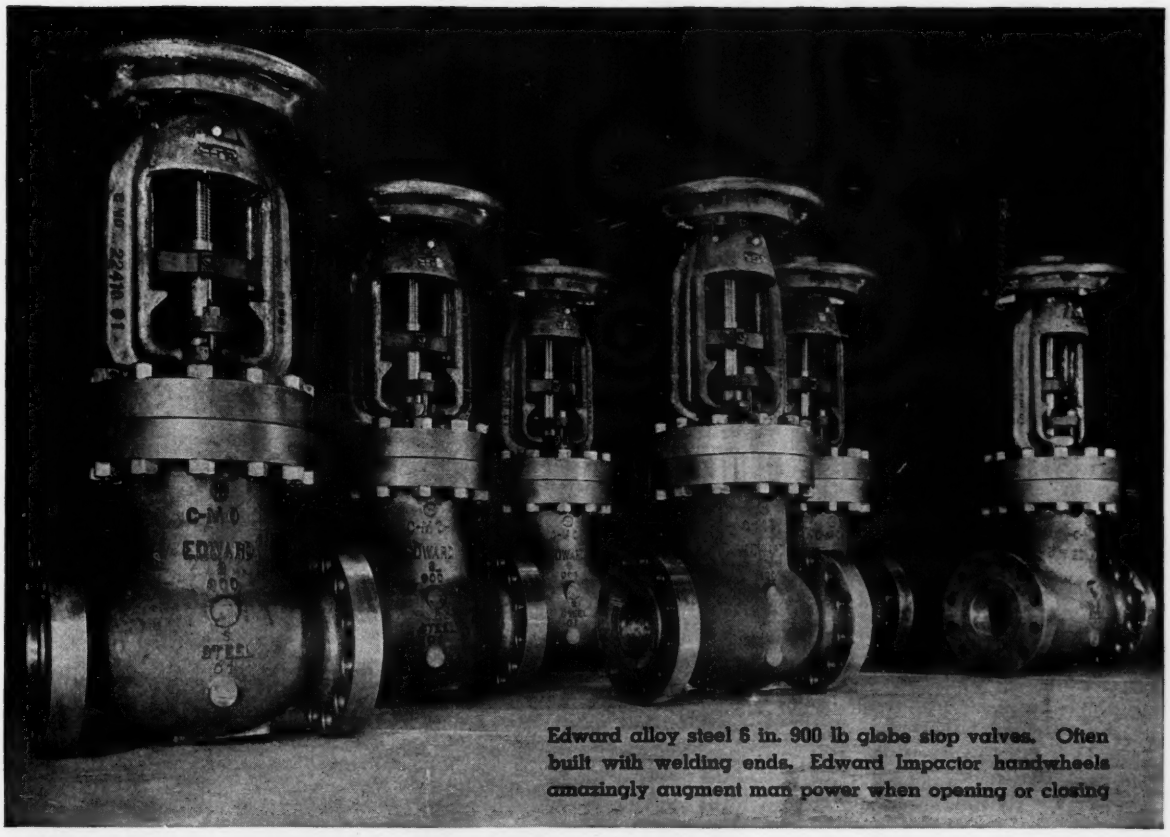
The field-control equipment for the synchronous motor, as well as the exciter, is now mounted on top of the motor. The synchronous motor can thus now be shipped with all wiring completed between the motor, exciter, and field control. The only wiring required on the job is between the synchronous motor and a line control switch, which can be of a wall-mounted full voltage or compensator type.

Portable Hand Lamp

INDUSTRIAL PRODUCTS CO., 703 W. Somerset St., Philadelphia, Pa., announces its new insulated portable hand lamp which takes standard or mill type lamps up to 60 watt. The lamp guard is constructed of a molded dielectric composition in a



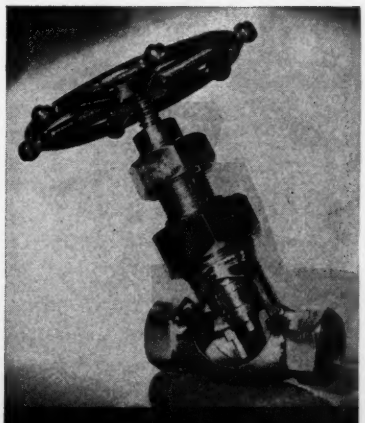
new design. It is sturdy, highly waterproof and heat resistant. This cylindrical open end guard with rugged end members supported by round composition dowels is high in non-conductive properties and resistance to moisture. The dowel rods do not obstruct light nor cast shadows.



Edward alloy steel 6 in. 900 lb globe stop valves. Often built with welding ends. Edward Impactor handwheels amazingly augment man power when opening or closing

GUARDED...

by Edward Stop Valves



Edward straightway forged steel globe valves, better year by year, deserve a place in every plant. Order Fig. 2688 (above) and other outof-stock Edward valves from Better Valves Catalog No. 101. Ask for copy.

• • •

THE EDWARD VALVE & MFG. CO., INC.
EAST CHICAGO INDIANA

IF you want to stop flow in a pipe, no valve equals a globe — or angle – stop valve in efficacy. It can cope with high temperatures and high pressures. It is first choice for throttling. And if leaks should develop – due to stray foreign matter, abuse, erosion, corrosion, improper service or old age – repairs may be made more cheaply and quickly than with other types of valves.

Built into Edward globe and angle stop valves are the results of three decades of intensive study of such vexing problems as are related to non-return, blow-off, and boiler feedline stop-check valves in which Edward has always specialized. Internal contours promote free flow without undue turbulence and cross currents. Carefully selected, painstakingly tested, and accurately machined materials prolong life. Keen inspection is maintained to catch mistakes. Design details are frequently revised to keep pace with new developments. Disks are positively guided by integral body ribs, self scouring, non-clogging, and assuring accurate seating.

For ease of operation, the Edward Impactor handwheels shown on the 6 in. 900 lb valves (above), or the super size knobbed handwheels on the forged steel valve (left) make friends with operators, save time and money, and improve plant appearance.

EDWARD VALVES

Pressure Controller

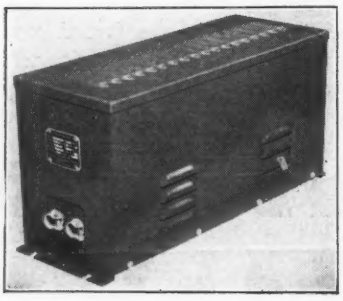
THE BROWN INSTRUMENT Co., 4508 Wayne Ave., Philadelphia, Pa., announces the development of their Air-o-Line Furnace Pressure Controller, which is adaptable to installation on all types of furnaces, stills, kilns, ovens and other similar equipment where very low differential or static pressure must be maintained.

Long past its pioneering stage, this instrument is applicable for controlling any pressure in the range from —5.0 in. H_2O to +5.0 in. H_2O. The controller is a sensitive, inverted-bell type draft indicator combined with the Brown Air-o-line control unit. Automatic reset and fully adjustable throttling range prevents the furnace pressure from lining out at some point other than the control point and eliminates over-correcting and cycling.

Automatic Voltage Stabilizer

A RAYTHEON Voltage Regulator permanently corrects the varying voltage conditions that are generally encountered and provides the constant AC voltage so essential for the effective operation of many electrical devices. Since the regulator will stabilize at any load within rating, it may be used as an accessory to devices already installed.

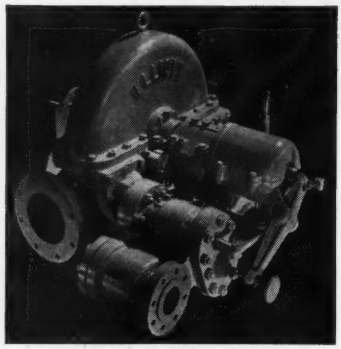
A typical Raytheon Voltage Regulator stabilizes an AC voltage that may be varying from 95 to 130 volts and holds it constant at 115 volts plus or minus 1 per cent automatically and instantaneously. It is a magnetic device without moving parts or adjustments. It can be made to operate from any commercial AC power source and deliver one or more required voltages with power outputs up to several thousand volt-amperes.



Bulletin D148-71-G has been prepared to give full information and electrical characteristics, dimensions, stock ratings, and prices. It contains illustrations and examples of how to select Voltage Regulators for specific applications and for general use. Copies will be mailed on request. Raytheon Mfg. Co., 168 Willow St., Waltham, Mass.

Turbines for Mechanical Drive

MADE by the Elliott Co., Jeannette, Pa., the type CY single-stage turbine for mechanical drive extends upward the size range of the Elliott Types AY and BY turbines introduced some years ago. Among features of these turbines are: centerline support, horizontally split casing, steam and exhaust connections in lower half casing, sensitive and sturdy centrifugal normal-speed governor, double-seated corrosion-resistant governor valve, rugged governor linkage, separate emergency overspeed governor, large-area built-in steam strainer with blow-down connection, stiff shaft rotor balanced both statically and dynamically, carbon packing rings removable without lifting upper half casing, handwheels for part-load economy, overload or emergency conditions, when desired, extra large bearings equipped with water-cooling features. These turbines are built for operation with steam pressures up to 600 lb. gage and temperatures up to 750 deg. F.



Water-Cooled Mercury Lamp

A 1000 WATT LAMP no thicker than a lead pencil is offered by the Westinghouse Lamp Division, Westinghouse Electric & Mfg. Co. A new principle is employed, mercury vapor in a very small "capillary" tube of quartz, operating at a very high pressure and water-cooled. The light it gives is exceedingly intense and concentrated.

This unique lamp is expected to be invaluable for use in photoengraving and other photographic processes as well as in searchlights and for therapeutic uses. Its rays are highly actinic and the amount of light emitted is high, 65,000 lumens. Moreover, since such a concentrated source can be focused with great accuracy it should find application in many other projection fields. It is about 12 times as brilliant as a filament projection lamp. Never before has such a powerful yet tiny source of so high intrinsic brilliance been available.

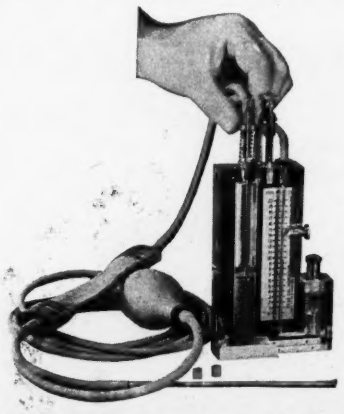
The new lamp consists of a quartz tube about ¼-in. in outside diameter, with a bore diameter of about 1/12 in.

The tube contains a globule of mercury and is capped at each end with a brass ferrule which serves as a terminal. Wires project from each ferrule into the bore, leaving a gap of about one inch. In operation the lamp is to be surrounded by a glass jacket through which water is circulated. The design of this jacket will depend upon the maker of the equipment which incorporated the lamp.

Initial research on this type of capillary lamp was conducted by Philips Glow Lamp Works of Eindhoven Holland; subsequent research and development in the Westinghouse Laboratories in Bloomfield, New Jersey.

Carbon Dioxide Indicator

OF INTEREST to those dealing with heating equipment, is the announcement by Julien P. Friez & Sons (a Div. of the Bendix Aviation Corp.), Baltimore, Md., of a new carbon dioxide indicator. This is of a new transparent composition



strong and durable and unaffected by the caustic solutions used in the indicator. The small size of the instrument is also obvious from the illustration. Readings are obtained by lining up the meniscus of the vertical mercury column with the graduations on the adjustable scale and the reflection of the meniscus in that polished scale.

Savings Begin When Nalco Comes In!

RIGHT in YOUR BOILER is where the curves for cost and efficiency begin . . . A loss here means a loss straight through your power plant . . . New equipment installed to reduce costs never gets a chance when savings are earmarked in advance . . . That's why we say "Savings begin when Nalco comes in!"

The Nalco System has an unusual record for reducing costs, improving performance and increasing safety. Let us show you the facts. No obligation. NATIONAL ALUMINATE CORPORATION, 6224 W. 66th Place, Chicago, Ill.

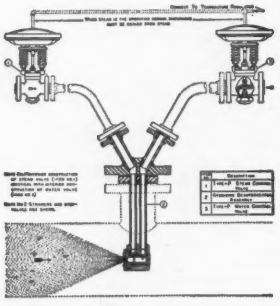
ANY WATER **NALCO SYSTEM** ANY PRESSURE

Inquiries other than domestic, *except those from U. S. Possessions, Canada and Mexico*, should be addressed to ALFLOC LTD., Bush House, Aldwych, London, W. C. 2, Eng. Canadian inquiries should be sent to ALUMINATE CHEMICALS LTD., 372 Bay St., Toronto, Ont.

Steam Atomizing Desuperheater

THE SPENCE steam atomizing desuperheater made by Spence Engineering Co., Inc., New York, N. Y., introduces a steam jet to atomize the cooling water so that mist is introduced into the steam pipe. This mist insures complete absorption of the water by the superheated steam.

In order to secure the proper results it is necessary to maintain a fixed relationship between the water and the steam used for atomizing purposes. In order to accomplish this, both the cooling water and the steam are controlled by two Spence Type-P single seat, Parabolic disc, streamlined control valves. These valves are controlled in turn by a standard Spence Type-T temperature pilot. As the temperature increases, the



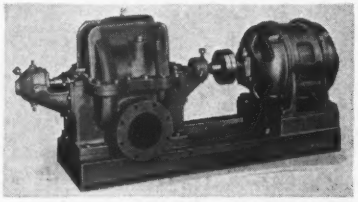
temperature pilot releases pressure from the diaphragms of the two control valves allowing them to open gradually, supplying the correct mixture of water and steam, which in turn maintains the correct temperature without flooding the main steam pipe with excess water.

A Spence steam atomizing desuperheater will operate on any load. In order to use the above mentioned unit, it is necessary to reduce pressure before desuperheating, or supply steam for atomizing purposes, at a higher pressure than that in the main pipe.

Nozzles are furnished in three sizes: No. 1 to fit a 2½-in. welding tee with a capacity of from zero to 40,000 lb. of steam per hour. No. 2 to fit a 5-in. welding tee with capacity between zero and 120,000 lb. per hour. No. 3 to fit an 8-in. welding tee having any capacity that might be required. These nozzles will fit any pipe equal to or larger than their respective tees.

Hotwell and Condensate Pump

WORTHINGTON PUMP & MACHINERY CORP., Harrison, N. J., announce the development of an improved two-stage centrifugal hotwell and condensate



pump. Featuring oversized suction openings, pick-up type impellers, and generous vents, the new line of pumps is offered for efficient removal of condensate under high vacuum, with minimum available submergence.

The casing of the new pump is of cast iron, horizontally split for ready access and removal of the rotor. Suction and discharge nozzles are located in the lower half of the casing, while an interstage passage is cast integral with the upper half of the casing. A liberal sized vent is provided to permit escape of entrained vapor.

Bronze impellers, of the single-suction enclosed type, designed especially for hotwell and condensate service, are mounted on the shaft with the suction openings facing inward. The back, or discharge, sides of the impellers are thus adjacent to the stuffing boxes, so that the latter are under first and second stage discharge pressures respectively, effectively preventing leakage of air into the pump.

GE Develops Low-Cost Resistance Welding Process

GENERAL ELECTRIC ENGINEERS have developed a low-cost resistance welding process of an electronic type to replace expensive soldering operations in the manufacture of such devices as radio sets, watches, small meters, industrial control devices, railway signal equipment, and business machines.

A current of several thousand amperes flows in the secondary circuit of the welder for a half-cycle which is precisely timed by an Ignitron tube and its associated control circuit. This control circuit includes a dial for regulat-

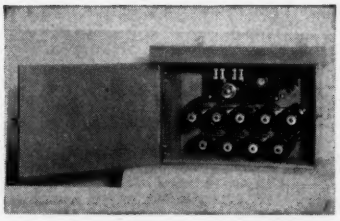
ing the heat by the phase-shifting method. The amount of heat is accurately determined by the duration of current flow; maximum heat is obtained with a current duration of slightly more than 1/120 of a second. The welding transformer and its associated equipment are suitably enclosed.

On other electrical devices, as well as on radio sets, tongs are used with the equipment in the welding of solid or stranded wires to terminals. Likewise, a suitable bench welder can be utilized to weld small studs (.010 in. to .050 in diameter) to flat surfaces with little or no marking on the opposite side of the sheet of metal. Similar equipment is suitable for the spot-welding of thin sheets of various alloys with little or no oxidation or discoloration.

Rectox Rectifiers for Cathodic Protection

TO COUNTERACT and practically eliminate galvanic action or electrolysis of underground pipe lines, cables, etc., a copper-oxide rectox rectifier developed for cathodic protection is announced by Westinghouse Electric & Mfg. Co.

These rectifiers have a rating range from 3 to 50 v., 1 to 125 amp. d.c. output. They consist of the necessary Rectox units for the desired rating, together with a two-winding transformer, disconnect switch, and terminal board, all mounted on sheet steel ventilated cabinet designed in some cases for outdoor use and in others for indoor use.

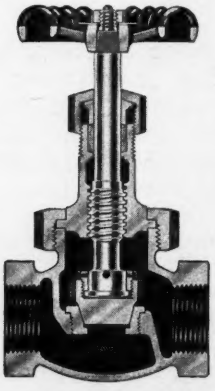


How much current and voltage is needed to protect a given length of pipe line can only be found out by actual trial, due to the variation in resistivity of coating and of soil condition already mentioned. Usually it has been found that if the pipe can be maintained negative to the earth by 0.3 v. or more, corrosion will be stopped.

The Rectox Copper-Oxide rectifier requires no maintenance as there is nothing to wear out and no attention beyond the occasional check of output which is required anyway due to the seasonal variations in soil and coating resistivity.

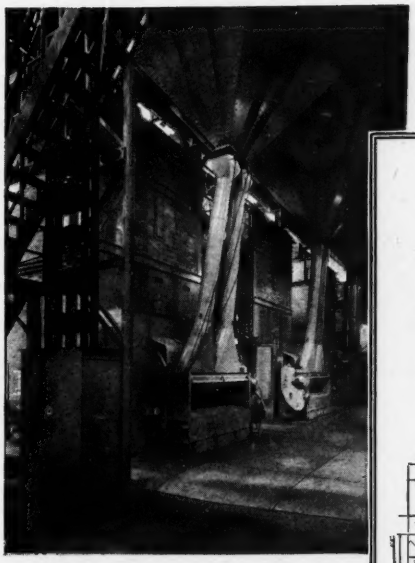
Bonnet Valve

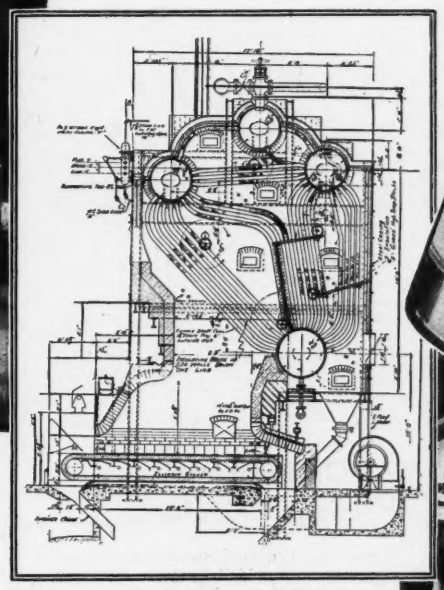
THE OHIO INJECTOR CO., 243-277 Main St., Wadsworth, Ohio, has now augmented its line of globe and angle inserted bonnet valves with a new line of union bonnet valves. This valve is for 200 lb. S.W.P. equipped with a 30 deg. plug seat and disc of Ohista metal. The seats and discs are 500-550 Brinell.

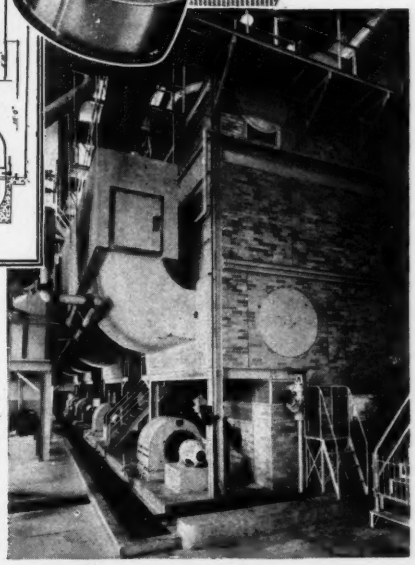


Ohista retains its hardness at high temperature, and resists wear, erosion, corrosion and galling. Foreign substances in the line such as boiler scale and metal cuttings are crushed without marring the seat or disc.

F. W. Cook BREWING COMPANY
EVANSVILLE, IND.







Installs
4-400 H.P.

Vogt WATER TUBE BOILERS

Write for Bulletins

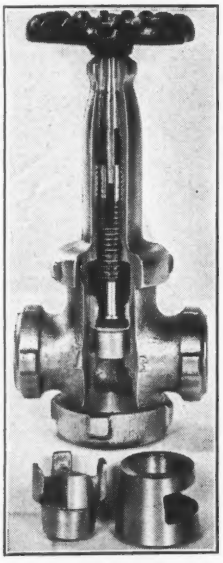
Successful breweries, like Cook's at Evansville, keep production costs down and pass the savings along by giving extra value in their product. Vogt boilers fit right in with such a policy, whether in a brewery or any other industry, by producing more steam per dollar of investment . . . . . a definite aid to lower production costs.

HENRY VOGT MACHINE CO., Inc., LOUISVILLE, KY.
NEW YORK · PHILADELPHIA · CLEVELAND · CHICAGO · DALLAS

Packless Valve

MONAT VALVE AND FORGE CO., 1007 Bessemer Bldg., Pittsburgh, Pa., is now manufacturing the new Packless "T" globe valve designed for pressures varying from 150 lb. to 1500 lb., and temperatures up to 1100 deg. F. They are available in sizes ranging from ½ to 4 in.

Outstanding features of these new packless valves include the all metal against metal construction, eliminating the necessity for the packing gland, packing and packing nut, and the Veriquick renewable seat and slip disc of high Brinell metals which can be changed without removing the valves from the line.

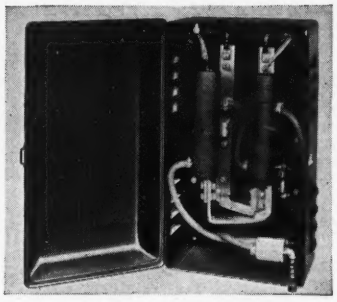


To insert a new seat, simply unscrew the cap from the base, eject tapered seat ring by screwing down on hand wheels, slip in new seat ring, tighten base cap and the line is ready for service. The change can be done in a flash, eliminating the necessity of removing valve from line, which effects considerable savings in time and labor. Old seats and discs may be reground on the bench for future service.

Recticharger

THE NEW Raytheon Recticharger does everything necessary to keep a storage battery fully charged except adding the water to make up for evaporation. According to the manufacturer they have built into the Recticharger an almost human-like ability to change the charging rate in accordance with the needs of the battery. An untrained attendant, therefore, can charge batteries with all the skill of an experienced service man. If the batteries are located at an unattended point, the Recticharger will assume full responsibility for automatically keeping them fully charged.

Inside the Recticharger is the Raytheon designed control unit which continuously matches the Recticharger output current rate to the current drawn from the battery. This type of charging always keeps the battery in a 100 per cent charged condition, because the current is returned to the battery as fast



as it is taken out. By preventing overcharging or under-charging maximum battery life is obtained.

In order that the Recticharger may operate unattended it is built so that it will not require any replacement of parts under normal operating conditions. Conversion of a.c. to d.c. is accomplished by copper oxide rectifying units, which have been operated at the manufacturer's plant on life tests for over 10 yr. without any indication of wearing out. The control unit is a transformer product and therefore does not have any moving parts. The other components have the same long life expectancy and the whole assembly is enclosed in an attractive metal cabinet for wall mounting.

Rectichargers are made for all popular battery voltages in sizes required for all the usual applications. Raytheon Mfg. Co., 168 Willow St., Waltham, Mass.

Low Cost Electronic Welding Contactor

FOR WELDING mild steel products and other readily-welded metals, a new "weld-o-trol" electronic power switch for controling the primary of welding transformers and suitable for use with existing timing devices, is announced by Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa. With either sealed-off or continuously pumped ignitron tubes, the Weld-o-trol offers an instantaneous power switch for producing uniform welds, and is free of moving parts, arcing contacts and noise. Available ratings, are roughly equivalent to 300 and 600 amp. conventional welding contactors.

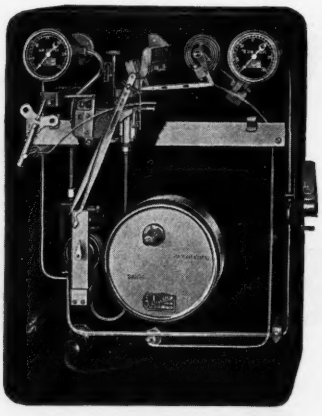
The Weld-o-trols equipped with sealed-off tubes consist of a sheet metal cabinet in which are mounted a bus bar assembly, electrical connections and a flow switch. The assembly is of the same general construction for all tube ratings, but has copper and construction suitable for the current ratings involved.

The only electrical connections required are; one power cable entering the unit and one leaving the unit—the Weld-o-trol acting as a single pole, single throw switch—and two control leads from the timer. No added control voltage is required, as the Weld-o-trol contains all necessary voltages for operating it and, therefore, no additional power supply should be inserted in the control circuit.

A water flow relay insures not only adequate water pressure, but insures an actual flow of water through the ignitron tube and provides protection against either water failure or stoppage of the drain line. A pressure switch is used on the pumped Weld-o-trols. The cooling water should come direct to the Weld-o-trol from the supply line and may discharge either to the drain or to the inlet of the cooling system on the welder or one of its branch lines. About two gallons of water per minute are required for the sealed off type while the pumped type requires slightly more water.

Recording and Controlling Instruments

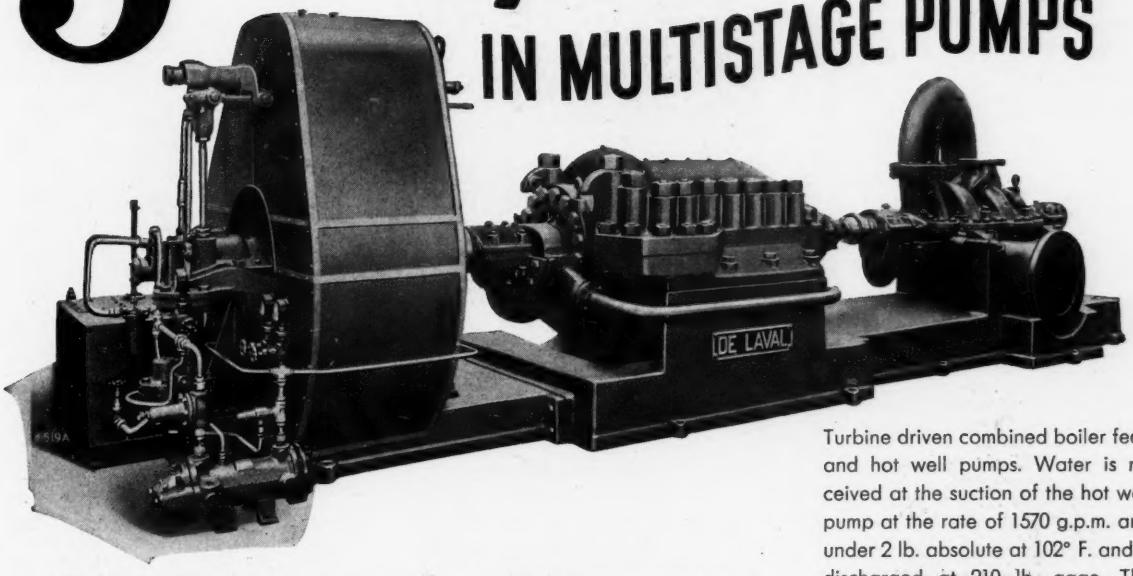
C. J. TAGLIABUE MFG. CO., Brooklyn, N. Y., announces a new line of TAG recorders and recorder-controllers with 10 and 12 inch charts. The new recording thermometer and pressure gage present many new features of design which include interchangeable calibrated tube system that can be readily replaced and need be checked at one point only; stainless steel pen arm that can be removed easily for cleaning or replacement; precision-built capillary fountain pen design with draftsman's



split-nib; pen arm movement designed for strength, lightness and rigidity supported by bearings at both ends.

In addition to all the features found in the recording thermometer, the TAG recorder-controller is offered in either the "On-Off" or throttling control model. The "On-Off" model with the simple non-adjustable flapper fits all ordinary temperature control applications. The throttling model utilizes an adjustable calibrated flapper which provides an exact sensitivity adjustment. This design permits easy adjustment of the throttling range to coincide with any considerable apparatus lag.

3 "Stop Leaks" IN MULTISTAGE PUMPS



Turbine driven combined boiler feed and hot well pumps. Water is received at the suction of the hot well pump at the rate of 1570 g.p.m. and under 2 lb. absolute at 102° F. and is discharged at 210 lb. gage. The boiler feed pump receives 1455 g.p.m. under 169 lb. gage at 260° F. and discharges against 1186 lb. gage. The turbine, running at 1770 r.p.m., receives steam at 815 lb. gage and 900° F. and exhausts against 5 lb. gage. This is the SIXTH De Laval unit of this kind ordered for a large central station. 3606

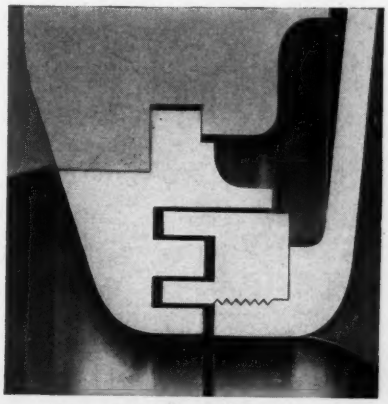
AS the boiler feed pump in a large high pressure steam plant often requires 1000 hp. or more to drive it, sustained efficiency reduces power costs materially.

Centrifugal pump efficiency is influenced by leakage (1) back through the joint which separates discharge chamber from suction, (2) through the thrust balancing device, and (3) at the point where the shaft penetrates the diaphragms.

In De Laval Multistage Pumps special measures are taken to reduce all three forms of leakage:

1. Impeller and diaphragm are protected against wear at the running joint by LABYRINTH WEARING RINGS, which reduce leakage and, at the same time, permit large clearances.
2. The disk balancing arrangement employed in De Laval pumps has axial rather than radial clearance, and adjusts itself automatically to maintain close clearance with minimum leakage, regardless of wear.
3. With De Laval single suction impellers the leakage head between stages along the shaft is small. The shaft is protected at this point by a renewable sleeve and the diaphragm by a renewable bushing.

These and other matters relating to multistage centrifugal pump design are discussed in new literature, which will be sent upon request.



De Laval Labyrinth Wearing Rings

DE LAVAL *Steam Turbine Co.*
TRENTON, N.J.

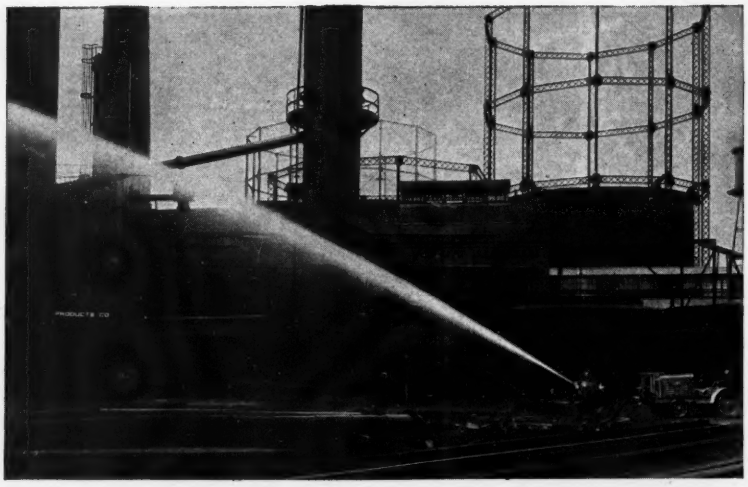
MANUFACTURERS OF STEAM TURBINES, PUMPS — CENTRIFUGAL, PROPELLER, ROTARY DISPLACEMENT; CENTRIFUGAL BLOWERS AND COMPRESSORS; WORM GEARS; HELICAL GEARS; HYDRAULIC TURBINES AND FLEXIBLE COUPLINGS · · · SOLE LICENSEE OF THE BAUER-WACH EXHAUST TURBINE SYSTEM

Fire Pump

AUXILIARY fire protection for factories, warehouses, docks and industrial plants is afforded by a new special duty fire pump, factory-installed as part of the "Clarktor-6" industrial tractor. The centrifugal type pump, meeting all test requirements of the National Board of Fire Underwriters, can handle any kind of water. In practice, the very high pressure small nozzle supplied creates a fine mist at the end of the stream of water, thus quenching the blaze.

A floating, flexible drive between motor and pump is provided by a power take-off. Automatic primer primes the pump and keeps it primed by means of a vacuum from the motor intake manifolds. When taking supply through a 4 in. suction opening from a 30 lb. hydrant, the pump will deliver 400 gal. per min. at 120 lb. pressure, with the motor running 1800 r.p.m. which is its normal controlled speed when operating the tractor. Pump capacity and speed may be increased by adjusting motor governor. The tractor power plant consists of a 46 hp., 6-cylinder engine, equipped with air cleaner and renewable cartridge type oil filter.

The pump is installed on the front end of any "Clarktor-6" tructractor behind the bumper plate. This makes it easily accessible for servicing. When used as a pumper, the machine's bumper plate is lifted up out of the way and rests over the engine hood. Clark Tructractor. Battle Creek, Mich. are the manufacturers.

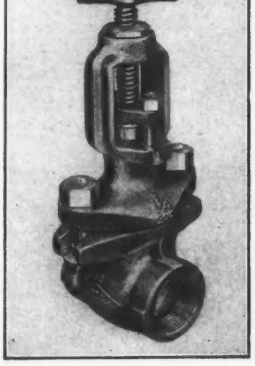


Stainless Steel Valves

CORROSION-RESISTING stainless steel valves are now available to industry in a most advanced line. By "Corrosion-Resisting Stainless Steel," is generally meant some combination of chromium and nickel with small additions of silicon, molybdenum, copper, columbium, titanium, etc., the balance being iron. The expression, "18-8," for example, refers to an 18 per cent chromium and 8 per cent nickel content.

These new valves manufactured by Jenkins Bros., 80 White St., New York City, are regularly made of cooper 18-8 S and cooper 18-8 SMO, each having a carbon content limited to a maximum of 0.10 per cent. Both are highly resistant to corrosion, but cooper 18-8 SMO is used under most severe conditions and is particularly adapted to sulphite pulp mills. It is safe to state that these two alloys will take care of almost 90 per cent of all corrosion-resisting requirements. In cases where neither of these valves can be recommended, valves of other alloys will be considered on special order.

They are available in seven different styles—solid wedge or double disc gate valves, union bonnet or bolted bonnet regrinding globe or angle valves, and bolted bonnet "Y" valve; all either screwed or flanged, in sizes ½ to 3 in.



Photrix Universal Photometer

THE PHOTRIX UNIVERSAL PHOTOMETER is a new sensitive portable light measuring instrument—one of the most sensitive ever built. For general purposes, it is equipped with a single photocell capable of distinguishing light values down to 1/100 ft. candle.

The instrument consists of a wooden case with carrying strap containing a galvanometer and a photo-electric element. The latter is connected to the instrument by means of a flexible cable and rests in a compartment of the case while the instrument is not in use. The scale of the instrument is arranged under an angle of 45 deg. so as to be easily read from the top as well as the side. It is calibrated in foot candles and has four measuring ranges which are selected by means of a 4 point switch operating a series of shunt resistances.

The main field of application of the Photrix Photometer consists in measuring low and medium values of illumination. If the illumination to be measured is so high that the instrument shows full-scale deflection while the switch is set at the highest measuring range, then, a baffle with a suitable opening should be placed in front of the photocell. In the lowest, i. e., most sensitive measuring range, the instrument has a full scale deflection of 2.5 ft. candles, each of the 50 divisions representing 0.05 ft. candles. It is possible to distinguish illumination values down to 1/100 ft. candle.

The Electrocell self-generating photoelectric element of the Photrix Photometer is hermetically sealed in a stainless steel casing with an optical glass window. This element operates for an unlimited period of time without any known chemical of physical reaction taking place inside of it. Its color sensitivity exceeds that of the human eye in the blue as well as in the red. By means of a special green filter, this excess sensitivity can be eliminated so that the element reacts to colors just as the eye.

If extreme sensitivity is required and if the illumination is to be measured on a large surface the instrument can be furnished with a double cell and for certain purposes multiple cells can be provided.

A smaller model (Model B) is provided which has only three measuring ranges, the most sensitive of which has a full scale deflection of 12 ft. candles. The highest range goes up to 1000 ft. candles which can be further extended by means of baffles.

In the case of both model A and B, calculators in the form of circular slide rules can be furnished to convert the readings into exposure readings for photographic purposes.

Special literature on the Photrix Universal Photometer can be obtained from Dr. F. Loewenberg, 10 East 40th street, New York, N. Y.

Motor Trolley

AMERICAN ENGINEERING CO., Philadelphia, Pa., announces the development of a new motor trolley, called the Type "RB". Features of the "RB" Motor Trolley are its short wheelbase, low headroom, four-wheel drive, and balance. Curves with a radius down to 7 ft. can be easily negotiated. Headroom varies from 1 ft. 9 in. to 3 ft. 10 in., depending on the capacity of hoist and (height) of lift. The four trolley wheels are all gear driven, providing maximum tractive effort. Balance is secured by means of an adjustable counter-weight.

According to the specifications, all trolley wheel and gear shaft bearings are heavy duty Hyatt roller bearings. Gears are cut, not cast. The trolley wheels are cast steel with machined rolling surfaces. The motor is ball bearing, fully enclosed and designed especially for hoist service. The controller is of the drum type, fireproof, completely protected from dust and moisture. The controller is operated by pendant cords.

"~~18~~ 31 Years Service— —Good For Many More!"

"It is the Terry Wheel that counts."—Indestructible,—one piece, long lived, rim protected, efficient.—
Descriptive bulletins on request.

THE Terry Turbine illustrated below was installed in the plant of the Eagle Lock Company in September 1907. For seven years it was in daily service driving an exciter. Since then it has been furnishing direct current for night lighting and week-end service.

The original wheel is still in the machine as well as the governor mechanism and governor valve. In the words of the operating engineer "it has given ~~18~~ 31 years service and is good for many more."

This, of course, does not mean that every Terry Turbine will perform in the same manner, but every Terry Turbine with the same care and attention will deliver the same satisfaction. By replacing the few wearing parts the life of a Terry Turbine may be prolonged almost indefinitely.

Terry Turbines are built in all sizes and for all steam conditions from 5 to 1500 H. P.

THE TERRY STEAM TURBINE COMPANY
TERRY SQUARE, HARTFORD, CONN.
Offices in Principal Cities in the U. S. A., also in Important Industrial Foreign Countries

T-949

This advertisement first appeared in 1925. The rotor of this Terry Wheel Turbine was recently inspected and found to be in good condition after 31 years of operation.
THE TERRY TURBINE

News from the Field

THE RESEARCH PRODUCTS CORP., with offices and plant at Madison, Wis., has recently purchased, from the C. F. Burgess Laboratories, Inc., the buildings and land at 1011-1015 East Washington Avenue, Madison, Wis. Officers of the corporation are Howard F. Weiss, President; Kemper Slidell, Vice-President; Max H. Kliefoth, Treasurer; Milton J. Shoemaker, Secretary; and Miss Bertha Weisman, Assistant Secretary and Treasurer. James Payton is Sales Engineer of the Air Filter Division and Kemper Slidell is Manager of the Water Conditioning Division.

What formerly was known as the Burgess air filter, is being manufactured and marketed by the Research Products Corp. under the name of Walton air filter. Future plans include an expansion of the air filter line to provide filter units for many new industries and applications.

ANNOUNCEMENT is made of the purchase by Julien P. Friez & Sons Division of Bendix Aviation Corp., Baltimore, Maryland, of the business of Nicostat Products, Inc., of Buffalo, New York. The Nicostat Co. has developed Magnetic Gas Valves, providing either slow or quick-acting performance, and based upon the patented principle of the floating disc. The entire physical activity is being moved to Baltimore, and the transfer of personnel to Baltimore includes Nico Borresen, the Engineer, and G. F. Knowles, the General Manager. Mr. Knowles will take charge of the greatly expanded activity of the Gas Section of the Friez Division's Control Instruments Department.

THE CROCKER WHEELER ELECTRIC MFG. CO. announces the appointment of Wallace K. Brown as Vice-President and General Sales Manager, to succeed B. D. Christian who will continue in an administrative capacity.

THE INDIANAPOLIS MACHINERY & SUPPLY CO., INC., Indianapolis, Ind., of which H. Lewis is manager, has recently been appointed distributor of the complete line of mechanical rubber goods manufactured by the New York Belting & Packing Co.

J. TIMOTHY O'HARA, formerly associated with the Amthor Testing Instrument Co., has organized his own sales agency to handle a complete line of testing and recording instruments. Offices are maintained at 620 East 43rd Street, Brooklyn, N. Y.

CHAIN BELT CO., Milwaukee, Wisc., has announced the election of Fred V. Gardner as Acting Treasurer to fill the vacancy created by the recent death of C. L. Pfeifer, and the election of John T. Brown, Vice-President to the Board of Directors. G. M. Dyke, Assistant Treasurer, was re-elected and A. F. Kessler, Chief Accountant, was elected an Assistant Treasurer.

JAMES F. TREAT, 51, chief engineer of the Pittsfield Electric Co., Pittsfield, Mass., died Sept. 28 at the Baker Memorial Hospital in Boston after a protracted illness.

ENTRY into the industrial roller bearing field has recently been announced with the appointment of Ahlberg Bearing Co. as nation-wide distributor for the products of Bower Roller Bearing Co. of Detroit. While the Bower Co. has been one of the largest manufacturers of roller bearings for almost a quarter of a century its sales in the past have been almost entirely confined to the automotive industry.

THE RELIANCE GAUGE COLUMN CO. announces that Bell & Eiss, Inc., Foshay Tower, Minneapolis, Minn., has been appointed to handle Reliance products throughout the state of Minnesota, western Wisconsin, and North and South Dakota, and I. C. DeHaven Engineering Co., 47 S. Penn St., Indianapolis, Ind., will represent the company in the major portion of Indiana and Louisville, Ky.

CLAYTON S. COGGESHALL has been appointed manager of the turbine division, central station department of the General Electric Company, succeeding the late Robert B. Beale, according to an announcement by M. O. Troy, commercial vice president. Mr. Coggeshall had served in the capacity of general assistant to Mr. Beale since March 1st of this year. Prior to that time he was manager of sales of the Lynn River Works turbine section.

BEAVER PIPE TOOLS, INC., announces the appointment of Avery Phillis as District Manager of the midwestern sales territory with headquarters in Chicago.

ON NOVEMBER 2-3-4 the Refrigeration Service engineers' society will hold its 5th Annual Convention and Exhibits of Refrigeration Equipment, Supplies and Accessories, at the Hotel Statler, Buffalo, N. Y. A number of leading manufacturers of the nation will exhibit. Each day there will be a number of technical papers presented.

STATEMENT OF THE OWNERSHIP, MANAGEMENT, CIRCULATION, ETC.

required by the Act of Congress of August 24, 1912, and March 3, 1933, of POWER PLANT ENGINEERING, published monthly at Chicago, Illinois, for October 1, 1938.

County of Cook, } ss.
State of Illinois, }

Before me, a Notary Public, in and for the State and county aforesaid, personally appeared Kingsley L. Rice, who, having been duly sworn according to law, deposes and says that he is the Business Manager of the Power Plant Engineering and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management (and if a daily paper, the circulation), etc., of the aforesaid publication for the date shown in the above caption, required by the Act of August 24, 1912, as amended by the Act of March 3, 1933, embodied in section 537, Postal Laws and Regulations, printed on the reverse of this form, to wit:

1. That the names and addresses of the publisher, editor, managing editor, and business managers are:

Publisher, Technical Publishing Co., Chicago, Ill.

Editorial Director, Arthur L. Rice, Chicago, Ill.

Editor, R. E. Turner, Chicago, Ill.

Business Manager, K. L. Rice, Chicago, Ill.

2. That the owner is: (If owned by a corporation, its name and address must be stated and also immediately thereunder the names and addresses of stockholders owning or holding one per cent or more of total amount of stock. If not owned by a corporation, the names and addresses of the individual owners must be given. If owned by a firm, company, or other unincorporated concern, its name and address, as well as those of each individual member, must be given.)

Technical Publishing Co., Chicago, Ill.
Arthur L. Rice, Chicago, Ill.
Charles S. Clarke, Chicago, Ill.
Kingsley L. Rice, Chicago, Ill.
Ralph E. Turner, Chicago, Ill.
Andrew W. Kramer, Chicago, Ill.
John O. Aarvold, Chicago, Ill.
Otto Kaad, Chicago, Ill.
Walter Painter, Chicago, Ill.
Edwin C. Prouty, Chicago, Ill.
Richard H. Morris, Chicago, Ill.
Madge W. Rice, Wilmette, Ill.

3. That the known bondholders, mortgagees, and other security holders owning or holding 1 per cent or more of total amount of bonds, mortgages, or other securities are: (If there are none, so state.)

There are none.

4. That the two paragraphs next above, giving the names of the owners, stockholders, and security holders, if any, contain not only the list of stockholders and security holders as they appear upon the books of the company but also, in cases where the stockholder or security holder appears upon the books of the company as trustee or in any other fiduciary relation, the name of the person or corporation for whom such trustee is acting, is given; also that the said two paragraphs contain statements embracing affiant's full knowledge and belief as to the circumstances and conditions under which stockholders and security holders who do not appear upon the books of the company as trustees, hold stock and securities in a capacity other than that of a bona fide owner; and this affiant has no reason to believe that any other person, association, or corporation has any interest direct or indirect in the said stock, bonds, or other securities than as so stated by him.

5. That the average number of copies of each issue of this publication sold or distributed, through the mails or otherwise, to paid subscribers during the twelve months preceding the date shown above is.....
(This information is required from daily publications only.)

KINGSLEY L. RICE,
Business Manager.

Sworn to and subscribed before me this 4th day of October, 1938.

JOHN O. AARVOLD.

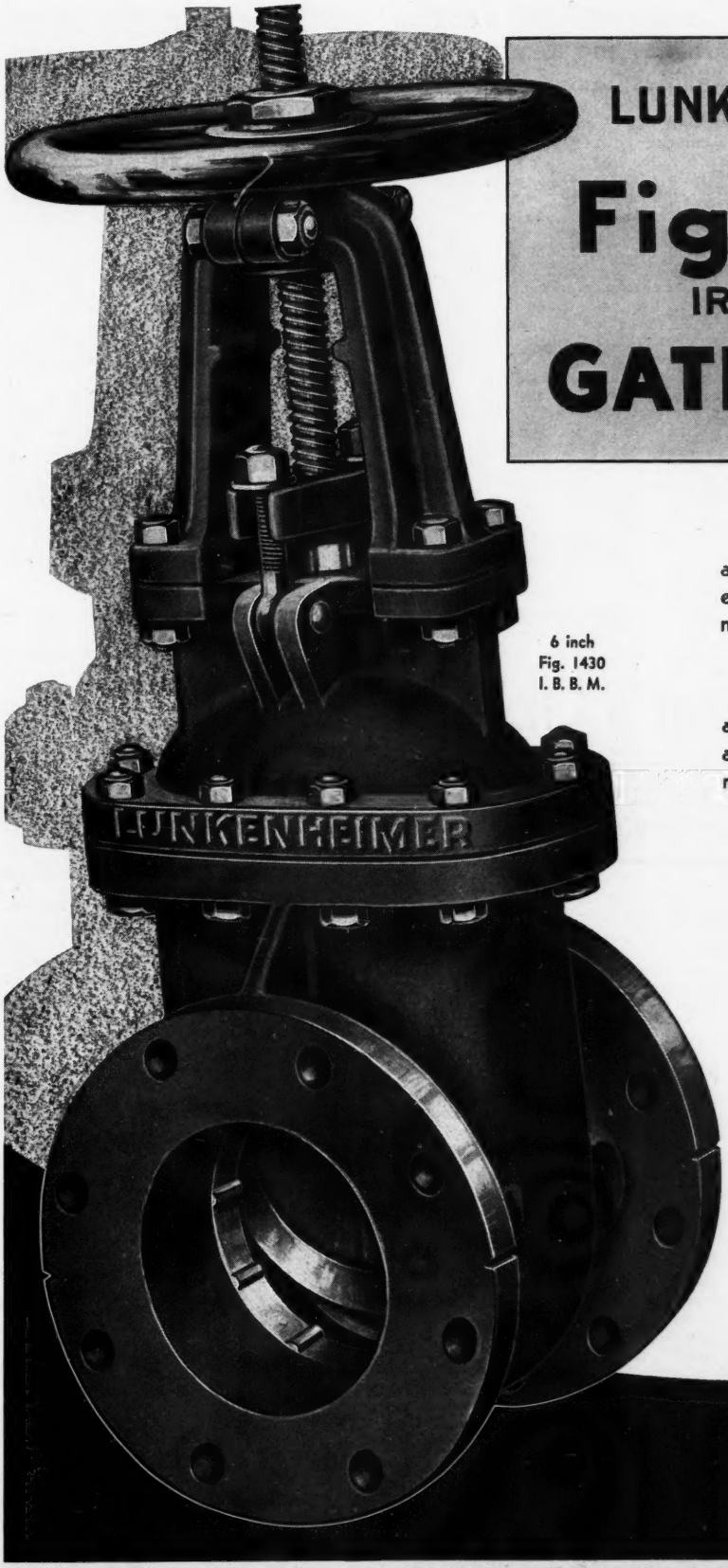
(My commission expires March 20, 1940.)

LUNKENHEIMER

Fig. 1430

IRON BODY

GATE VALVE



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W. H. & L. D. Betz, 235 W. Wyoming Ave., Philadelphia, Pa., announce the following changes in their organization:

George Bernauer, a graduate of Marquette University, formerly chemical engineer of the Milwaukee Sewage Commission, will work in conjunction with the Chicago laboratories in serving the Milwaukee area.

J. A. DeWinter, graduate of Purdue University, formerly chemical engineer with the Public Service Co. of Indiana, has been appointed to fill the vacancy created in the Detroit office by the death of A. H. McDowell.

The company also has a series of five lectures on water treatment and the chemistry of water to be given under the personal supervision of James K. O'Brien, general manager of sales and service. These lectures will be given in the Ball Room of the Hotel Statler in Buffalo beginning Monday evening, November 14th and continuing each Monday evening for 5 weeks. In Cleveland they will be given in the Euclid Room of the Hotel Statler beginning Tuesday evening, November 15th and continuing for five weeks. Admittance may be arranged through correspondence or by personal application at the opening lectures before eight o'clock.

Consolidation of Lexington Utilities and Kentucky Utilities Co.

The Lexington Utilities Co. and Kentucky Utilities Co., both Kentucky corporations, have filed with the Federal Power Commission a joint application for authority under Section 203 of the Federal Power Act to merge or consolidate all their respective facilities subject to the jurisdiction of the Commission.

The agreement of consolidation, under which the two companies propose to merge, provides that one share of 6 per cent preferred stock ($100 par value) of Kentucky Utilities Co. (the consolidated corporation) and $8.33-1/3 in cash will be delivered to the holders of the $6.50 preferred stock of Lexington Utilities Co. in exchange for and upon surrender of such stock for cancellation. The Public Service Commission of Kentucky, by an order dated July 7, 1938, authorized the statutory consolidation and the issue or assumption of securities by the consolidated corporation and, applications for approval of the proposed issue or assumption of securities have been filed with the Securities and Exchange Commission.

For the Engineer's Library

Any Catalogs that you wish will be gladly sent. Write Power Plant Engineering.

Electrical Equipment

B-A "De-Ion" Power Fuse—Dry Boric-Acid power fuses used for the protection of high-voltage circuits and equipment, applicable in utility and industrial power plants, and for all high-voltage power use, indoor and outdoor, are described in an illustrated booklet. Copies of this booklet F.8450 may be secured from Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Rectox Rectifiers for Cathodic Protection—Rectox Rectifiers designed to counteract galvanic action and electrolysis by maintaining a small direct current from ground to structure, a technique known as "cathodic protection" are described in a 4-page illustrated leaflet. Copies of this leaflet, descriptive data 27-450, may be secured from Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

An Ignitron A-C Welding Contactor—Without Timing—A 4-page illustrated booklet under this title announces a new Weld-O-Trol electronic power switch for controlling the primary of welding transformers and suitable for use with existing timing devices and for welding mild steel products and other readily welded metals. Copies of this booklet, Descriptive Data 18-345, may be secured from Westinghouse Electric & Mfg. Company, East Pittsburgh, Pa.

Lightning Arresters—Types MP and IC direct-current lightning arresters, especially applicable for railway and industrial service, are described in a 6-page illustrated booklet published by Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Prime Movers

Diesel Tractor—Operating costs and specifications of the 25-horsepower "Caterpillar" Diesel D2 Tractor are given in a new 32 pp., 2 color booklet, Form 4757, just published by Caterpillar Tractor Co., Peoria, Ill.

Diesel Engine—The Vertical Four Cycle direct-injection type Diesel engine is the topic of discussion in Bulletin S-500-B 35. It is well illustrated giving construction, operation and specifications. Worthington Pump & Machinery Corp., Harrison, N. J.

Engine Lubrication and Deterioration, prepared as a report of an investigation by Spitzglass and Zucrow, Consulting Engineers, is presented in book form for distribution to interested persons by Pines Winterfront Co., 1135 N. Cicero Ave., Chicago, Ill. The investigation dealt with internal combustion engines and is of importance to all those interested in lowering operating and maintenance costs, greater efficiency and longer life of engines. The report includes sections under the headings: The General Problems; Emulsion Sludge; Oxidation Sludge; Corrosion and Erosion; Water Accumulation in Crankcase; Crankcase Dilution; Piston Ring Sticking; Abrasive Wear; Starting Difficulties; and Fuel and Oil Economy. The book contains a great amount of fundamental information on lubrication and lubricants and gives numerous references where additional information on various phases of this subject may be secured.

Heat Exchangers

Green's Ringstay-Type Economizer—Bulletin 167 under this title describes and illustrates a cast-iron economizer with a special ringstay type joint, a type of construction which makes it possible to use the cast-iron economizer for relief pressures up to 450 lb. The Ringstay-Type Economizer can be furnished with either horizontal or vertical tubes and may be baffled to obtain proper rate of gas and water flow. Copies of Bulletin 167 will be gladly sent on request to The Green Fuel Economizer Co., Inc., Beacon, N. Y.

Surface Condensers—A 24-page bulletin, C-8, under this title contains discussions of various subjects relating to condensers such as heat transfer, tube layout, tube sizes and materials, methods of installing tubes, ejectors and pumps, curves on heat transfers, friction loss, logarithmic mean temperature difference, condenser formulas, and a pressure-temperature conversion table. Elliott Co., Jeannette, Pa.

Mechanical Power Transmission

Ball and Roller Bearing Lubrication is the title of a 42-page booklet covering general constructional features of bearings, their care and lubrication. Definite recommendations, covering type, size, speed and temperature, are summarized in a one page table. The Texas Co., 135 East 42nd St., New York, N. Y.

Rex Roller Chains and Sprockets is the title of 128-page catalog No. 333 giving list prices and dimensions of standard and non-standard roller chains, stock and made-to-order sprockets; engineering information on the selection and application of roller chain drives is also included. Chain Belt Co., 1600 West Bruce St., Milwaukee, Wis.

Miscellaneous

Regulations prescribing the periods of time the records of public utilities and licensees must be preserved, covering: Corporate and general; plant and depreciation reserve; treasury; revenue accounting and collecting; pay roll and personnel; purchases and stores; operations; statistics; miscellaneous records, have been promulgated by the Federal Power Commission, effective as of Aug. 1, 1938. Copies may be had from the Superintendent of Documents, Washington, D. C. Price 10 cents.

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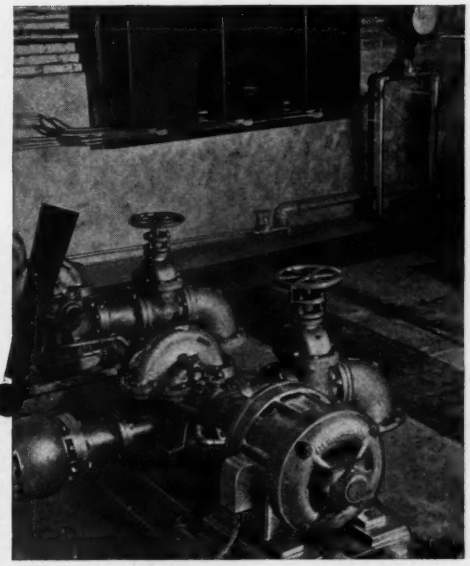

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Cash in on increased pump efficiency. Find out how you can save money with new pumps. Let an Allis-Chalmers pump man, a trained engineer, analyze your pumping problems . . . show you how much you can save . . . give you actual figures in dollars and cents!

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Trucks—Cars—Turntables are the topic of discussion in Bulletin 228 of the Whiting Corp., Harvey, Ill.

Lumnite, a structural cement, is illustrated and described in a new folder issued by the Atlas Lumnite Cement Co., 135 E. 42nd St., New York, N. Y.

Ash Removal—The Ashveyor and the Jetveyor systems of ash removal are illustrated and described in two new bulletins recently issued by the Brady Conveyors Corp., Chicago, Ill.

Cleaner—A new folder fully describing the use and character of Magnus Vapor Cleaner has just been issued by the Magnus Chemical Co., Garwood, N. J.

Solenoid Valves—Bulletin No. S-1 illustrates and describes Davis solenoid valves. The types listed are for general service on steam, air, gas and liquid. Davis Regulator Co., 2508 S. Washtenaw Ave., Chicago, Ill.

Instruments

Recording Gages—A new 7-page bulletin contains information and illustrations about recording gages and accessories. The importance of spring construction is discussed, with particular reference to the all-welded steel helical movement, the diaphragm spring movement, the spiral spring movement and the Bourdon spring movement. For copies of bulletin No. 208 write The Foxboro Co., Foxboro, Mass.

Instruments for measuring and controlling temperature and for testing paper are illustrated and described in Bulletin M-382 which has been issued by Thwing-Albert Instrument Co, 3339-41 Lancaster Ave., Philadelphia, Pa.

How To Use Ellison U Path Steam Calorimeter is the title of a 4-page pocket-size leaflet which is unusually comprehensive and complete. Ellison Draft Gage Co., 214 West Kinzie St., Chicago, Ill.

Air Machinery

Compressors—A new 20-page catalog describes and illustrates the Unitair stationary and semi-portable air compressors. The bulletin fully describes improvements that have been made and also covers power unit driven types. Bulletin A-22 may be had on request to The Sullivan Machinery Co., Michigan City, Ind.

Ventilating Fans—The Wing-Scruplex Fan, a propeller type fan is described in this new illustrated bulletin. It covers fans for ordinary ventilation applications as well as acid-resisting fans, dye-house fans, motor-drive and pulley-drive, protective shutters and pent-houses. Especially valuable is a table for easy selection of fans to deliver air through ducts of various sizes and lengths. Capacities, horsepower and construction details are included for fans rated from 850 to 78,000 cu. ft. per min. A copy of Bulletin F may be had on request to L. J. Wing Mfg. Co., 154 W. 14th St., New York, N. Y.

New Engineering Books

Kent's Mechanical Engineer's Handbook — Design — Shop Practice Volume. Eleventh Edition. Robert T. Kent, Editor in Chief. 1378 pages, 5¾ by 8¾ illustrated, flexible binding. John Wiley and Sons, Inc., 440 Fourth Ave., N. Y. 1938. Price $5.00.

This, second volume of Kent's, constitutes Volume III in the new Wiley Engineering Handbook Series. The Wiley Handbook Series, consists of a general volume (Vol. I—Eshbach's Handbook of Engineering Fundamentals) together with four other volumes, II and III of which are Kent's Mechanical Engineer's Handbook and IV and V are Electrical Handbooks. Volume II Kent's "Power" volume appeared in October 1936. Now, in May 1938, Kent's Design and Shop Practice makes its appearance.

"Kent" has appeared in two volumes before—but in these earlier editions the two volumes were obtained simply by dividing the one volume edition in half and binding the two parts as separate volumes. The present two volumes, however, constitute something entirely new in the long history of "Kent." In the first place, in accordance with the new concept of the function of a handbook, material fundamental to all engineering has been removed to the separate volume referred to, Esbach's. The division of Kent into two volumes is logical. The first volume deals with the entire field of Power with its applications that are of interest to the mechanical engineer. The second volume, just issued, covers in detail, methods in Design and Shop Practice.

This volume covers the following subjects:

General Properties of Materials; Iron and Steel; Corrosion and Corrosion-Resistant Metals; Non-Ferrous Metals and Alloys; Non-Metallic Materials; Fabricated Materials; Strength of Materials; Mechanism and Mechanics; Fastenings; Mechanical Springs; Rotating Members; Keys, Cotters, Pins, Tapers and Fits; Bearings; Gearing; Control Mechanisms; Vibration and Noise; Structures and Buildings; Industrial Heating Processes; Forging Practice; Foundry Practice; The Machine Shop; Woodworking; Materials Handling; Mechanical Power Transmission; Electric Motors and Their Control; Miscellaneous Shop Equipment; Safety Engineering; Mathematical and Other Tables; Index.

It forms an excellent companion volume to the first volume on Power and provides the most practical and most complete data on the various branches of mechanical engineering that one could ask for.

Thermodynamics, Fluid Flow and Heat Transmission. By Huber O. Croft. Published by McGraw-Hill Book Co., 330 W. 42nd St., New York city. Size 6 by 9 in. 296 pp., cloth bound. Price $3.50.

In spite of its cumbersome title, this book fills a real gap in engineering literature, combining as it does in one unified treatment three subjects fundamentally related but ordinarily treated separately. After an introductory chapter on definitions and units, there is a brief 20 page treatment of dimensional analysis and the balance of the space is about evenly divided between the three major subjects. Dimensional analysis involves the collection of variables into groups to express the relation between variables without necessitating actual evaluation of experimental constants. Dimensional analysis and the principle of similitude involved in model tests are widely used in experimental work.

The book is intended as an elective coordinating senior or graduate course for all branches of engineering and as such pre-supposes a working knowledge of thermodynamics, hydraulics, and, mathematics through calculus and differential equations. As such the rather brief and highly mathematical treatment is apt to prove discouraging reading to the engineer whose mathematics are rusty or who is old fashioned enough to demand a concrete physical concept rather than a mathematic formula.

Even these will, by sliding over the more involved mathematics and taking some things for granted, have no difficulty in following the general development, however, while students and those who take their mathematics seriously will find the book fully up to their expectations.

Metallurgy. By Carl G. Johnson, R. S. Dean and J. L. Gregg. Published by The American Technical Society, Drexel Ave. at 58th St., Chicago, Ill. Size 5½ by 8½ in., 144 pp., cloth bound. Price $1.50.

It is surprising to find that such a distinguished trio of authors have written so simple and readable a book about a subject which is fundamentally involved. The text is intensely practical and covers the entire field of physical metallurgy from the treating and shaping of metals and alloys through the testing and behavior in service. It is, however, intended only as an introduction to the science of metallurgy, a background course for those interested in pursuing some particular phase further or for engineers who wish to have a broader general knowledge of the production and utilization of ferrous and non ferrous metals and alloys. A list of references is given in the back for those desiring to pursue the subject farther Carl G. Johnson is assistant professor of mechanical engineering at Worcester Polytechnic Institute, R. S. Dean is chief chemist of the Bureau of Mines and J. L. Gregg is with Battelle Memorial Institute.

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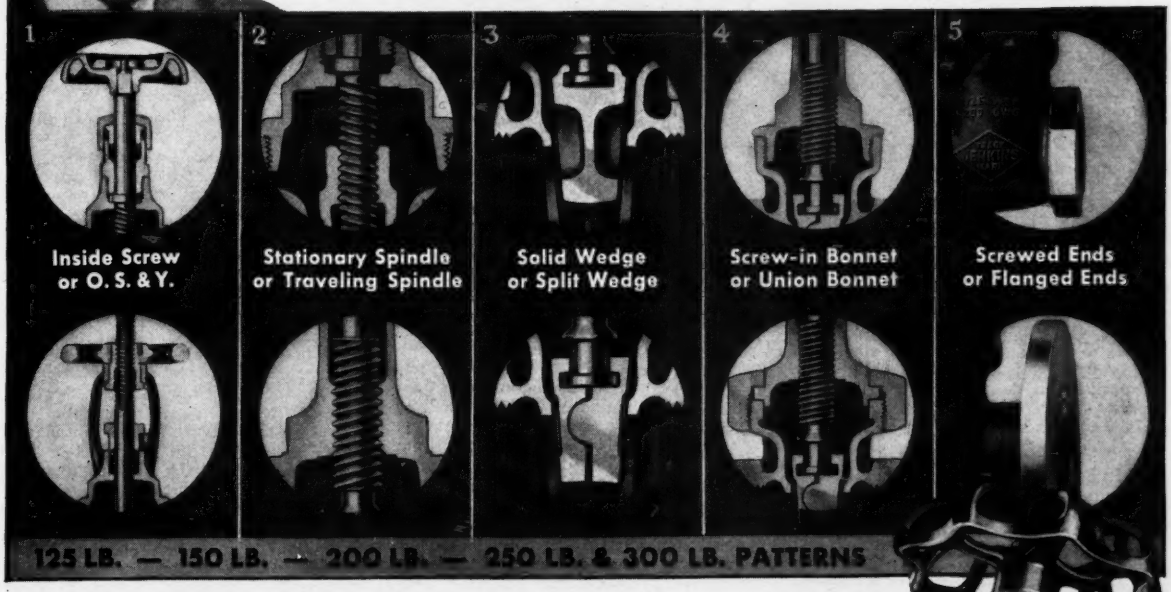
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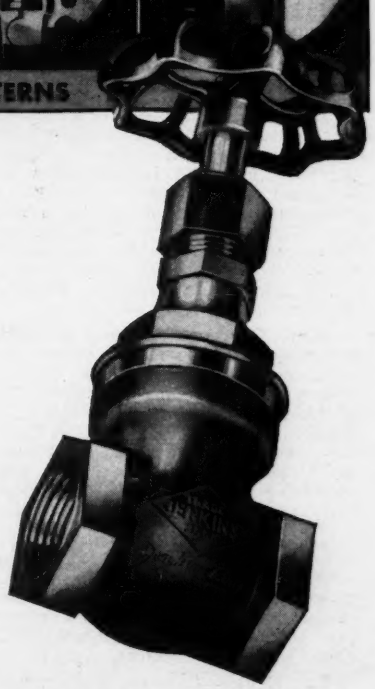

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Power Plant Construction News

Calif., Burbank—City Council has plans maturing for new municipal electric power plant, for which a bond issue of $350,000 has been voted, and further appropriation of $548,000 is being arranged through reserve fund and Federal aid to make total of $908,000 for project. Installation will be turbo-generator units to cost $270,000; boiler plant, $175,000; condenser system, $80,000; feed water system, $35,000, and miscellaneous equipment. A power substation is estimated to cost $30,000. J. H. Cambridge is superintendent of Department of Public Service, in charge.

Conn., Bridgeport — Bridgeport Brass Co., plans installation of electric power equipment in new addition to tube mill, for production of brass, copper and other metal tubing, 110x220 ft. Entire project will cost close to $150,000. Fletcher-Thompson, Inc., 1336 Fairfield Avenue, Fairfield, Conn., is architect and engineer. Work is scheduled to begin soon.

Ill., Chicago—City Council has approved construction of an electric power plant at Chicago municipal airport, to be used for emergency light and power service. Estimate of cost not announced. Proposed to begin work soon. Oscar E. Hewitt, City Hall, commissioner of public works, is in charge.

Ind., Bloomington—Board of County Commissioners, Court House, will receive bids until Nov. 9 for stoker unit for power house at county infirmary, as per specifications on file.

Ind., Indianapolis—Board of Trustees, State School for Deaf, 1050 East Forty-sixth Street, has plans maturing for extensions and improvements in boiler plant at institution, to include installation of two 300-hp. watertube boilers, chain grate stokers, combustion control apparatus, ash-handling system and miscellaneous equipment. Bevington-Williams, Inc., Indiana Pythian Building, is consulting engineer.

Kan., Osborne—Common Council has plans under way for extensions and improvements in municipal electric power plant, including installation of additional equipment. Cost close to $50,000. Paulette & Wilson, 1006 Kansas Avenue, Topeka, Kan., and Farmers' Union Building, Salina, Kan., are consulting engineers. Bond issue has been approved for work.

La., Abbeville—City Council is considering extensions in municipal electric power plant and waterworks station, including installation of new 1400-hp. engine unit and accessory equipment. Cost estimated close to $90,000. J. E. Kibbe is mayor, in charge.

La., Eunice—Common Council has plans maturing for new municipal natural gas distributing system, including control station and operating facilities. A bond issue of $115,000 has been voted for project.

Mich., Sturgis—City Council plans expansion and improvements in municipal electric power plant, including installation of new equipment. Cost estimated close to $275,000. Financing has been arranged through Federal aid.

Mo., Kansas City—Empire Storage & Ice Co., Guinotte and Chestnut Streets, plans early erection of new four-story and basement cold storage and refrigerating plant, 74x110 ft. Cost over $75,000, with equipment. Alfred Benberg, 10 West Ninth Street, is consulting engineer. Ralph Wilkerson is general manager.

Mo., Kansas City—Security Stove & Mfg. Co., 1630 Oakland Street, plans installation of power equipment in new two-story addition to stove and range plant, 85x125 ft. Entire project will cost about $50,000.

Mo., Lee's Summit — Common Council has plans under way for new municipal electric power plant. Proposed to use Diesel engine-generator units and accessories. Cost about $150,000. Financing is being arranged through Federal aid. E. T. Archer & Co., New England Building, Kansas City, Mo., are consulting engineers.

Mo., Odessa — City Council has plans for new municipal electric power plant and electrical distributing system. Proposed to use Diesel engine-generating units and auxiliary equipment. Cost about $139,000, of which $63,000 will be secured through Federal grant. E. T. Archer & Co., New England Building, Kansas City, Mo., are consulting engineers.

Mo., St. Louis—Johnston Tin Foil & Metal Co., 6106 South Broadway, plans installation of electric power equipment in new one-story addition to metal foil-manufacturing plant, 100x100 ft. O'Meara & Hills, 5709 Waterman Street, are architects. Erection is scheduled to begin soon. Entire project will cost close to $60,000.

Neb., Cedar Rapids—Cedar Rapids Irrigation and Power District, Cedar Rapids, H. C. James, consulting engineer, is planning a hydroelectric power development in Boone County, Neb., including power dam, generating station, transmission and distributing lines, power substations and other structures. Cost about $1,500,000. Financing is being arranged through Federal aid.

Neb., Hartington—City Council has plans under way for new municipal electric power plant. Cost about $114,500, of which $55,525 will be represented by a Federal grant. H. H. Henningson Engineering Co., Union State Bank Building, Omaha, Neb., is consulting engineer.

N. Y., Frankfort—Union Fork & Hoe Co., Dublin Avenue, Columbus, Ohio, plans installation of electric power equipment in proposed new additions to branch agricultural equipment-manufacturing plant at Frankfort, where tract of land has been acquired. Entire project will cost over $250,000.

Ohio, Columbus Grove — Common Council plans extensions and improvements in municipal steam power plant, used for central-heating service, with installation of additional equipment. Cost estimated over $30,000. Financing will be arranged through Federal aid. Carl J. Simon & Associates, Van Wert, Ohio, are consulting engineers.

Ohio, New Washington — City Council has plans under way for new municipal electric power plant. Cost about $123,200. Financing is being arranged through Federal aid. Carl J. Simon & Associates, Van Wert, Ohio, are consulting engineers.

Okla., Drumright — City Council has plans under way for new municipal electric power plant and electrical distributing system. Cost about $280,000. Bonds for $154,000 have been authorized, with remainder of fund to be secured through Federal aid. William L. Austin, Cushing, Okla., is consulting engineer.

Okla., Stillwater—Board of Trustees, Oklahoma Agricultural and Mechanical College, Stillwater, plans new power house at institution for light, power and central heating service. Cost about $675,000, of which about $303,750 will represent a Federal grant. Phillips A. Wilbur, at college, is engineer.

S. C., Abbeville—City Council has arranged financing in amount of $435,000 through Federal aid for municipal hydroelectric power development and will proceed with work at early date. Project will include power dam, generating station with initial installation of two hydraulic turbine units of 1500 and 500-kw. capacity, power substation and transmission lines.

Tenn., Chattanooga—Star Box & Printing Co., 1414 Chestnut Street, plans installation of electric power equipment in new one-story addition to corrugated box-manufacturing plant, 300x500 ft. An award for building erection has been let to H. K. Ferguson Co., Hanna Building, Cleveland, Ohio. Entire project will cost close to $300,000.

Texas, Fredericksburg—City Council has plans maturing for new municipal electric power plant. Cost estimated about $155,000, of which $100,000 will represent a bond issue, recently voted and remainder a Federal grant. Joseph E. Ward, Harvey-Snider Building, Wichita, Kan., is consulting engineer.

Texas, Houston—American Chain & Cable Co., 905 Live Oak Street, plans installation of power equipment in new one-story plant, 150x150 ft., on Cliette Street. Entire project will cost over $80,000. Erection will be placed under way soon.

Texas, Robstown—City Council has plans maturing for new municipal electric power plant, using Diesel engine-generator units and accessories. Fund of $274,000 has been arranged through bond issue and Federal aid. Proposed to begin work soon. Garrett Engineering Co., Houston, Texas, is consulting engineer.

Wis., Black River Falls—Common Council has plans under way for new Diesel-electric power plant. Cost about $120,000 with generator units and accessories. Financing is being arranged through Federal aid. Mead, Ward & Hunt, State Journal Building, Madison, Wis., are consulting engineers.